ACTION LEVELS

FOR

HAZARDOUS WASTE SITE WORK

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Christopher S. Marlowe —— Printed November 24, 1995

I. Introduction

In the early 1980s, when hazardous waste response and remediation became an industry, the industrial hygienists who developed its health and safety procedures borrowed heavily from two sources: 1) standard procedures for chemical manufacturing, and 2) standard procedures for work with chemical weapons. Many of the health and safety procedures we selected were more appropriate to a manufacturing facility than to a construction site.

This course work book describes techniques by which complex risk-assessment decisions needed to protect the health and safety of hazardous waste site workers can be reduced to actions in response to factors observable by the work team. Action levels at which industrial hygienists start to monitor community air are briefly described in this book because efforts to protect community air quality are often based on the work site monitoring.

Our approach rests on the careful establishment of action levels at which evacuation or additional personal protection is required. Industrial hygienists should base action levels on allowable exposure limits for the contaminants present (See Section 3) and the response factors of the air monitoring instruments they use. (See Section 8).

II. Sources of Exposure Limit Values

Many regulatory agencies and professional organizations publish limit values for worker exposure to hazardous substances. The guidelines normally address exposure by inhalation because the other routes of exposure (injection, ingestion, and dermal absorption) are controlled by personal hygiene and work practices. This section discusses the use of the PEL (Permissible Exposure Limit), the REL (Recommended Exposure Limit), and the TLV (Threshold Limit Value) exposure limits and the levels IDLH (Immediately Dangerous to Life and Health).

A. Health Effects

1. Occupational Safety and Health Administration (OSHA)

The Occupational Safety and Health Administration (OSHA) publishes Permissible Exposure Limits (PELs) in its standard 29 CFR 1910.1000 et seq. Because federal law requires us to observe the OSHA PELs, industrial hygienists don't set action level higher than the corresponding PEL. In 1993, a federal court struck down OSHA's 1989 revision of the PELs, making the 1971 PELs the current list. Many prudent contractors observe the lower of the 1971 or 1989 PELs without reference to their status in the courts.

2. American Conference of Governmental Industrial Hygienists (ACGIH)

The American Conference of Governmental Industrial Hygienists (ACGIH) publishes a list of Threshold Limit Values (TLVs). The TLVs appear annually in the booklet Threshold Limit Values and Biological Exposure Indices that is available from ACGIH, 6500 Glenway Avenue, Cincinnati, OH 45211. The TLVs are widely accepted and applied, both in industry and in hazardous waste work. Many prudent contractors observe the lower of the PELs or TLVs as a liability control measure.

ACGIH publishes the Guide to Occupational Exposure Limits, which you can use to compare the published limit values. The PEL/TLV column of Exhibit A lists the lower of the PEL or TLV values for 600 common chemicals. All available IDLH values for those chemicals also appear. If the TLV for a contaminant is lower than the PEL, Exhibit A shows the TLV.

3. National Institute for Occupational Safety and Health (NIOSH)

The National Institute for Occupational Safety and Health (NIOSH) is a research agency. Any exposure limit that NIOSH recommends, and OSHA does not adopt, becomes a Recommended Exposure Limit (REL). When a REL exists, but a PEL does not, OSHA requires us to implement the REL. RELs are listed in the NIOSH Pocket Guide to Chemical Hazards, DHHS Publication #90-117. Many Industrial hygienists ignore the REL values unless neither a TLV nor a PEL exists for the compound.

NIOSH has also established the levels Immediately Dangerous to Life and Health (IDLH). Exposure to a chemical at the IDLH can cause irreversible health effects or escape-impairing symptoms (e.g., severe respiratory irritation) within 30 minutes. The IDLH values can also be found in the NIOSH Pocket Guide to Chemical Hazards. Workers may enter areas where they suspect an IDLH condition may exist only in protective equipment levels A or B. Exhibit A also lists IDLH values that NIOSH or the authors have published. Some author-developed "IDLH values" appear in the table. These usually consist of 10% of published acute human LD_{Lo} levels, or 25% of the lower flammable levels.

4. Manufacturer - Derived Exposure Limits

A very convenient source of non-official exposure limits is manufacturer material safety data sheets. If the manufacturer has the courage to choose an exposure limit value for its product, you probably won't go wrong if you adapt it to your use in developing action levels. If you don't buy from that manufacturer, however, they would rather avoid credit for the help they gave you.

5. Company - Derived Exposure Limits

When no PEL, REL, or TLV exists for a compound, the IH is faced with the undesirable choice of developing his own exposure limit for the compound, or asking the field team to work in supplied-air breathing apparatus for weeks or months. Because any protective device can create new hazards, or increase old ones, the authors feel that the use of carefully chosen limits is often the better approach.

Deriving this type of limit may require the advice of risk assessment specialists. The two procedures below usually generate project-specific limits that are within an order of magnitude of limits that a regulatory agency would set.

a. Derivation by Analogy

We sometimes develop "project-specific" exposure limits by analogy. Of course, these limits provide imperfect discrimination points between hazardous and non-hazardous. The examples below show techniques by which the authors have derived project - specific exposure limits.

Dimethyl disulfide. On one project, we found dimethyl disulfide in area samples at levels between 0.21 and 1.71 ppm. Dimethyl disulfide does not have a published exposure limit. The chemical (with a limit) that is most like dimethyl disulfide is methyl mercaptan, which has a PEL of 0.5 ppm. We calculated an exposure limit of 1.88 ppm for dimethyl disulfide by multiplying 0.5 ppm by (12.46 / 3.3), the ratio of the airborne lethal concentrations (LC_{Lo}'s) found in the published literature.

Levels we measured on the example project ranged from 11% to 91% of this project-specific exposure limit. Because project-specific exposure limits don't provide good separation points between hazardous and non-hazardous conditions, this exposure may represent a hazard. We recommended that the client keep exposure to dimethyl disulfide as low as reasonably achievable.

Alkylbenzenes. We proposed a project-specific exposure limit of 300 ppm for C-9 and C-10 alkylbenzenes and for propylbenzene. These compounds are important constituents of gasoline, kerosene, and stoddard solvent, which have PELs ranging from 300 to 500 ppm.

Terpenes. Because we found no analogous compound with a published limit value, we did not propose a project-specific exposure limit for terpenes. Our reports showed "mod tox" in the PEL space with the following explanation: "No permissible exposure limits are available for terpenes. We entered the notation "mod tox" in the exposure limit column to show that each terpene has an LD_{50} (the dose that kills 50% of a test population) between 1,000 and 5,000 milligram of terpene per kilogram of body weight. This range of LD_{50}s, which toxicologists call "moderately toxic," includes gasoline and fuel oils, which have PELs in the range from 100 to 400 ppm." If we faced these compounds on a hazardous waste site, we would probably have developed our limits using the risk assessment approach outlined below.

b. Derivation by Risk Assessment

When no established limit is available, and no appropriate analogy is apparent, the IH may derive an exposure limit for his work force by careful study of the compound's toxicology. Many organizations that are active in the hazardous waste field employ toxicologists who can help the IH set a risk - based limit. Because few company's can afford to conduct conclusive toxicology tests, some issues that might be solved through laboratory research will remain ambiguous. The company should resolve all uncertainties in favor of protecting workers.

Organizations in this industry have based conservative occupational exposure limits on:

- 0.1% of the lowest dose that causes non-cancer illness in animals when you have one toxicology study. (Remember to control chronic exposure for chronic toxicants and acute exposure for acute toxicants.) The example below shows a conversion from dose to concentration.

- 1% of the lowest dose that causes non-cancer illness in animals when you have a large set of toxicology studies.

- The one-cancer-case-per-million-exposed-persons guideline commonly accepted in the public health field. (NOTE: This is a very conservative approach. Some OSHA exposure limits produce risks of about one in 5,000.)

10^{-6} cancer probability

Example - Dioxin at a Wood Treatment Facility

Work teams often investigate or remediate hazardous waste sites at which pentachlorophenol was applied to wood. Although the ACGIH publishes useful limit values for phenol and pentachloro- phenol, no agency publishes a limit for air concentrations of the hexachlorodibenzodioxin that often contaminates the pentachlorophenol. At one site where the industrial hygienist decided not to develop a limit, the crews worked for three years in respirators because the soil contained five part per million of hexachlorodibenzodioxin.

Although many industrial hygienists possess enough toxicology training to complete a toxicological risk assessment and to determine what dose would produce a one in a million risk, employees often have greater confidence in the exposure limit if this dose were selected by a neutral party. The industrial hygienist in this example found, in a 1984 document proposing the de-registration of pentachlorophenol, that USEPA had decided that ingestion of 161 ng of hexachlorodibenzodioxin per kilogram of body weight per day (0.161 μg/Kg/d) would produce one case of cancer in a million exposed persons.

To use EPA's "allowable dose" in deriving a limit for airborne dioxin, this industrial hygienist had to decide what fraction of total committed dose would be represented by inhalation while on the job. In this case, the assumption that occupational inhalation was the only important route of exposure seemed merited. This assumption allowed the hygienist to calculate the concentration of this dioxin in air that would produce this "allowable dose" in an average female worker (who inhales more air per kilogram of body mass than an average male worker). The calculation looked like this:

$$\text{Limit} = 0.161\ \mu g/kg/d \times 58\ kg / 9.2\ m^3/d = 1\ \mu g / m^3$$

58 kilograms, and 9.2 cubic meters per day, are the mass and the eight-hour moderate- exertion breath volume of the average female worker as reported in the Radiation Health Handbook.

Although the authors continue to use this limit in spite of a dioxin exposure limit (10 picograms per cubic meter as a TCDD equivalent) proposed by the National Research Council, the example is provided as just that, an example of what procedure is .

2,3,7,8

6. Exposure Limit Notations

a. Duration of Limits

Limits published by all three sources are designed to be compared to a specific duration of sampling or monitoring. When the most important health effect occurs within a day of exposure, a ceiling limit usually applies. The ceiling value should not be exceeded even instantaneously. Limits preceded by a "C" in Exhibit A are ceiling values.

When the most important health effect occurs days or years after exposure, a time weighted average (TWA) limit applies. TWAs are compared to the air concentration averaged over a workday. Workers can be exposed to brief periods over the time weighted average, provided they are compensated by periods of exposure below the limit. Short term exposure limits (STELs) are guidelines that supplement many time-weighted average limits. They protect against acute effects (such as irritation, narcosis, and tissue damage) from substances that causes chronic toxic effects at lower levels. Most of the limits in Exhibit A are TWA limits. STEL limits are not presented in Exhibit A.

Excursions between the TWA and the STEL should be no longer than 15 minutes in duration, at least 60 minutes apart, and should not be repeated more than four times per day. Because the excursions are calculated into the eight-hour, time-weighted average, exposure during the rest of the day must be lower to compensate.

b. Extended Schedules

Hazardous waste personnel often work 10 or 12 hour days on waste sites. Most exposure limits assume eight-hour work shifts. For longer shifts, time-weighted average (but not ceiling or STEL) limits should be adjusted for the longer exposure, during which an employee could inhale more contaminant. ACGIH's TLV Committee suggests that industrial hygienists use the approach outlined in Brief and Scala's 1975 paper, "Occupational Exposure Limits for Novel Work Schedules." They direct us to multiply the limit value by a reduction factor (RF) that is calculated using the equation below.

$$\text{Reduction Factor} = \frac{8 \times (24 - \text{hours})}{\text{hours} \times 16}$$

When the workday is 10 hours long, this calculation reduces the limit values by 30%. When the work day is 12 hours long (a fairly normal work day for a site investigation), it reduces the limit values by 50%.

c. "Skin" Notation

Some listings in Exhibit A are followed by an "S" notation. This notation suggests that absorption through skin, mucous membranes, or the eyes can contribute significantly to the systemic exposure. Employees should use increased skin protection when dealing with these materials.

B. Action Levels for Other Effects

Unless the client for which the contractor is working has more restrictive policies, work teams will limit their field work as described below.

1. Flammability

Whenever the work space air may contain gases or vapors at explosive concentrations, teams should monitor for combustible gas. the "four-agency" document Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities suggested the following action levels for combustible gases or flammable vapors:

Concentration	Action Taken
<10% of LEL	Work may continue. Consider toxicity potential.
10 to 25% of LEL	Work may continue. Increase monitoring frequency. Some teams stop work at 10%. Avoid use of sparking tools.
>25% of LEL	Work must stop. Ventilate area before returning.

Remember that these limits apply to measurements taken wherever a spark might occur (for example, in a borehole during monitoring well installation), not only where personnel are located. Of course, the combustible gas limits assume that oxygen levels are high enough to allow the instrument to measure. Many prudent contractors prefer to cease work at 10% of the lower explosive limit without carrying out the intermediate step suggested above.

2. Oxygen Deficiency

Whenever the work space air may contain more oxygen, or less oxygen, than normal air, work teams will monitor for oxygen. Typical action levels for oxygen concentration are listed below:

Concentration	Action Taken
<19.5% O_2	Leave area. Re-enter only with Supplied air (e.g. SCBAs).
19.5 to 23.5% O_2	Work may continue. Investigate any changes from 21%.
>23.5% O_2	Work must stop. Ventilate area before returning.

When the air contains oxygen at 20%, it will support life. However, any agent that dilutes the air to the degree that oxygen is present at 20%, is itself present at 45,000 part per million. You would like to know what that agent is, and make plans based on any other hazards that it presents.

3. Noise

Whenever work team members must raise their voices to talk at a distance of three feet or less, they will wear hearing protection or monitor the work area for noise levels as described in OSHA standard 29 CFR 1910.95. Action levels for noise are listed below:

4. Airborne Pathogens.

Neither governments nor professional associations have published limits for occupational exposure to airborne microbial agents. Industrial hygienists in all fields of endeavor must use "seat-of-the-pants" judgment when their work force is exposed to microbial agents. Some approaches that you might consider are described below. *Aspergillus fumigatus* is used as an example.

One source of limit values that have tested for microbial agents consists of measurements that environmental hygienists have collected in tissue transplant wards at major hospitals. At the 1993 American Industrial Hygiene Conference and Exposition, A. J. Streifel reported that the Mayo Clinic observes no fungal infections among lung transplant patients when *aspergillus fumigatus* counts are below 2 colony-forming units per cubic meter (cfu/m³). This approach does not recognize that most employees are less susceptible to infection than immune-impaired patients, but does have a research "pedigree".

Another possible source of limit values are the concentrations found as a background in the ambient environment. It is not uncommon for *aspergillus fumigatus* to be present in the air of a home with many houseplants at 20 (cfu/m³). Although this approach uses none of the professional judgment you have cultivated over the years, you might be forced to use it.

Another possible approach to limit values is to accept a limit value for microorganisms in general. At the 1993 American Industrial Hygiene Conference and Exposition, Henk Heida reported that some Dutch hygienists have started to use the following limits:

Total microorganisms	10,000 (cfu/m³).
Gram-negative bacteria	1,000 (cfu/m³).
Microorganisms per species	500 (cfu/m³).

Another possible approach is to involve your company's medical consultant in standard setting. The doctors, however, show limited enthusiasm for this activity. One author used this approach following a survey for airborne microbes at a waste water treatment plant. The statement he made was:

> "We found no microbial agents that are frankly pathogenic. Common non-pathogenic and opportunistic bacteria were present on samples at 2,000 to 6,000 colony forming units per cubic meter. A microbe that is frankly pathogenic will make a healthy man sick, while an opportunistic bug only makes a sick man sicker. These agents can harm a person with already-impaired health. We recommended that the client release these data to its occupational physicians immediately, so that they can warn persons who may be at risk."

5. Off - Site Air Impacts

The industrial hygienist must often evaluate the impact of airborne contaminants that a remedial project imposes on off-site locations. Those measurements should be compared to exposure limits appropriate for the population as a whole (which several types of includes sensitive individual). We often compare the concentrations found at the property fence lines to the Ambient Concentration Guidelines published by the New York State Department of Environmental Conservation or the Ambient Air Guideline Concentrations that appear in Edward Calabrese's book Air Toxics and Risk Assessment. Exhibit B shows a comparison of typical occupational and residential exposure limits, to illustrate their relationship.

Community limit 480 10×10×4.2 Indoor Air AIHA Emergency Limits

C. Radiation

1. Is This Radiation Work?

Radioactive materials are often present on sites where you intend to investigate or remove chemical hazardous waste. As discussed in the section on Site History, Radionuclides are concentrated in waste streams by many ore-extraction processes. Each industrial hygienist must decide for his or her employer this question: "Are our employees 'radiation workers' who are subject to OSHA's 5 rem per year limit, or 'incidentally exposed workers' who are subject to the Nuclear Regulatory Commission's 100 millirem per year limit?" Of course, the NRC limit is more protective, but the OSHA limit allows your company to accept more contracts.

10-20 ... Background

2. Should We Monitor?

Whenever elevated levels of radiation may be present in the work space, work teams will monitor for radiation as described in their company's standard radiation procedures. Unless you know that concern about radiation has been eliminated by previous workers, you should monitor for radiation whenever you work at a plant site at which mineral ores were processed.

Before you monitor for anything, you should know what actions you will take in response to various levels. Example action levels for gamma radiation exposure are summarized below:

Intensity	Action Taken
<3 X background	Work may continue
>3 X background or 50 μR/hour	Radiation work zone. Notify industrial hygiene.
>250 μR/hour	Work proceeds only with industrial hygiene approval (the IH should seek advice from a health physicist.)
>2 mR/hour	Can you avoid this work area? Establish exclusion zone. Work requires health physicist's advice.
>10 mR/hour	Work must stop. Can you avoid this work area?

The table refers to exposure to radiation in Roentgen units. If beta radiation contributes significantly to the radiation hazard, develop a table similar to the above for beta radiation doses in rads or rem with the help of a health physicist.

3. Airborne Radionuclides

29 CFR 1910.96, OSHA's standard for ionizing radiation, references the table of Maximum Allowable Concentrations found in 10 CFR 20, the Nuclear Regulatory Commission's standards for radiation protection. In 1992, NRC renamed these limits "Derived Air Concentrations" and changed their values. NRC did not change the table number that appears in the OSHA reference, so the NRC immediately became the OSHA limits. You can use these limits for the radionuclides in the same way that you use OSHA's Permissible Exposure Limit for lead dust.

III. DETERMINING CONTAMINANTS OF CONCERN

In every forty-hour course, one or more students will complain about the difficulty of complying with the OSHA requirement to identify the, "Hazardous substances and health hazards involved or expected," at "completely unknown sites." Procedures for use at these sites are presented in part E of this section. However, because society will rarely pay your organization to investigate a problem unless they have some indication of a problem, you will rarely see a completely unknown site. This section talks about techniques for developing a list of suspected or anticipated contaminants.

A. Data Requirements

An industrial hygienist in manufacturing can evaluate exposure to the materials used in a manufacturing plant by examining their material safety data sheets, sampling the air for the chemicals that are present in those materials, and comparing the results of those samples to limit values published by OSHA, ACGIH, NIOSH, or the manufacturer of the material. Contaminant identification is more difficult in the hazardous waste industry.

The procedures that we will discuss in the rest of this paper require the industrial hygienist to determine the:

- Chemicals present at the site
- Media the chemicals are present in
- Concentrations of the chemicals
- Total quantities of chemical present

Evaluate the above questions using the information provided by your project engineers or scientists or through use of the procedures listed in this section.

B. Using Site History

1. Information From Analysis

Most projects that OSHA characterizes as "hazardous waste operations" occur on sites at which some samples have previously been collected. If adequate samples have previously been collected, use that information. Procedures for using the results of these analyses are presented in Sections IV through VIII of this paper.

2. Materials Understanding

Many work teams accept lists of site contaminants at face value. Experienced industrial hygienists, however, know that laboratory analysts can only quantify materials for which they test. We have often observed radioactive materials on sites that were only tested for lead, or dioxins on sites that were only tested for creosote.

You should try to remember, for example, that coal gasification sites are usually contaminated with polynuclear aromatic hydrocarbons. Field industrial hygienists also look for biodegredation products, like the vinyl chloride that is present when trichloroethylene is present in anoxic sub-surface soils.

Examples

Many hazardous waste site work teams report levels of "total petroleum hydrocarbons," (TPH) without any attempt to characterize the petroleum products that cause the reading. Whether the TPH consists of asphalt, lubricants, or diesel fuel matters greatly to an industrial hygienist. You can refine your understanding of the chemicals that your work teams will face by estimating the contributions of the old fuel tank, the grease pit, or the former coal yard to the result.

Municipal landfills contain food wastes that degrade to yield carbon dioxide and methane. The methane can build up to significant pressures. Field technicians have observed up to ten pounds per square inch. If the operators accepted industrial volatile solvents (which happened at most landfills, not just those that appear on the National Priority List), the methane pushes the solvent vapors toward the work team.

Ash from municipal incinerators is also common at these mixed municipal landfills. This ash is often caustic and contaminated with significant levels of lead, copper, and arsenic.

3. Information From Process History

Waste Creation

Although work teams sometimes enter sites at which they have no process history ("Kitchen sink" landfills are the most common example.), they will usually have some idea about the history of the site. This historical information is valuable for this reason: **Most waste is created during economic activities for economic reasons.**

The industrial hygienist should attempt to determine the processes used by the companies that may have disposed or discharged on the site. Many literature resources provide information about the processes by which products are made. Information about processes involved in physical item manufacturing can be found in industrial engineering sources, like those listed in the bibliography. Information about chemical product synthesis can be found in the reference books in the bibliography.

I would like to report that computer databases, such as the Illinois State Museum's Historical Hazardous Substance Data Base can help you identify site contaminants, but they don't yet contain the quantity or quality of data that hard-copy books do.

The industrial hygiene books I mention in the bibliography often yield hints about the contaminants of concern. If your office does not stock any of the resources described above, you probably <u>do</u> own the Merck Index, which lists the laboratory synthesis for most compounds. Although the synthetic approach used in chemical manufacturing can differ from the procedure described in Merck, the production process is a simple scale-up of the laboratory procedure more often than industry would like to admit.

Examples

Many metal ores contain only 2 to 10% of the metal of interest. The Bevill Amendment to the 1976 Resource Conservation and Recovery Act exempts the tailings (the rest of the ore, dumped after the refining process) from regulation. An understanding of the extraction process will help you identify hazards that could affect your work teams. Research into the process might reveal a potential for cyanide or mercury exposure at a gold processing site, or a potential for radium at a titanium dioxide processing site.

Wood treating in the United States has used three quite different processes: the creosote process, the pentachlorophenol process, and the chromium, copper, arsenate process. A process awareness can help you identify site contaminants. One company, for example, completed an investigation of one type of contaminant on a wood treating site without asking whether the other processes were used there. This awareness can also help you anticipate conditions that promote movement through the site. Pentachlorophenol applied as a sodium salt, for instance moves more quickly in groundwater. The pentachlorophenol is often associated with polychlorinated dibenzodioxins and furans.

Example Problem

Your work teams are about to collect surface and subsurface soil samples and to install monitoring wells at an abandoned chemical factory. A phase one audit (conducted by another organization) of the site states that the factory once made aniline, and contains observations about soil staining. The report, however, does not postulate on the content of those stains. Use the information in Exhibit C to identify the contaminants of concern.

4. Information From Site Observation

Even when neither process history nor analytical data are present, you can derive reasonable guesses as to the contaminants present on site from the "presenting syndrome" that motivates your clients (even regulatory agencies have "clients" of a sort). If you were called in because children in a playground cough and weep when the wind blows vapors from the site, worry more about aldehydes than about PCBs. If, on the other hand, neighbors report orange and green stains in the creek, but no strange odors, worry more about chromium contamination than about benzene or isopropyl acetate.

Although you already use this "observation technique," we suggest that formal application of descriptive toxicology can help you narrow the range of contaminants of concern rapidly. One author identified a "mystery contaminant" at an air pollution episode as epichlorohydrin because exposed persons reported that their lips would swell and become numb just before they became ill. If the limits of your knowledge about descriptive toxicology leave you unsure of this approach, get your hands on the <u>Index of Signs and Symptoms of Industrial Diseases</u> that Betsy Fay and Charles Billings wrote, and NIOSH published, in 1980.

IV. Using the Exposure Limits You Have Selected

A. Action Levels for Known Contaminants

Exposure to a contaminant at any concentration is rarely beneficial. Field workers must make every reasonable effort to keep their exposure as low as reasonably achievable (ALARA). When exposure is unavoidable, teams can use engineering controls and personal protection to keep their exposure well below established limits.

Work teams should determine action levels at which additional personal protection is required. The site health and safety plan (H&SP) must state exposure limits and action levels for each contaminant. The action levels are reviewed and approved by the industrial hygienist (IH) as part of the H&SP. For many contaminants, an appropriate action level at which to don level C protection is one half its OSHA PEL, NIOSH REL, or ACGIH TLV, whichever is lowest. (NOTE: This manual will rarely discuss the choice between half-face and full face respirators, because the authors have a bias in favor of full-face respirators). Exposures; to chemicals that air-purifying respirators will not control, above the maximum use concentration for your respirator, or above one third of the IDLH, require level B. When the identities of the vapors or gases are unknown, many industrial hygienists approve the use of action levels based on total atmospheric concentrations (See Section 5) until they have identified all of the important airborne contaminants.

Level B @ MUC @ IDLH/3
Level A @ IDLH/2

Example Problem:

Cresol (TLV = 5 ppm) is the only volatile compound on the site. Will an air-purifying respirator provide protection? What action level would you use for upgrade from level D? What action level would you use for upgrade from level C?

B. Action Levels for Mixtures

1. Traditional (ACGIH) Approach

While there is a wealth of information on inhalation exposure to a single chemical, there is little information on the combined effect of two or more chemicals. Exposures to a combination of chemicals that have unrelated effects (e.g., narcosis and irritation) are evaluated independently. Chemicals that have related effects (e.g., cancer and liver disease), are evaluated by adding the exposure levels as a fraction of their exposure limits [$\%\ \text{allowed} = \sum(\text{Conc}_n \div \text{Limit}_n)$].

Hazardous waste work exposes workers to low levels of multiple chemicals that may have synergistic effects. All exposures must, therefore, be kept as low as reasonably achievable (ALARA).

<u>Mixture Results</u>

The potential for several chemicals to create a combined toxic effect is often assessed by use of the TLV mixture formula, in which the hygienist sums each exposure divided by its limit value. The ACGIH warns us not to use the mixture formula for agents with unrelated effects, like cancer and irritation. The authors often use the mixture formula for all chemicals in spite of this warning, because this approach produces (at worst) false alarms, but never produces false security.

Example:

Hydrogen sulfide and hydrogen cyanide exposure should be evaluated as a combination, because they cause the same type of toxicity by the same mechanism. In one project, we found hydrogen cyanide at levels ranging from 2.08 and 3.01 ppm, for an average of 2.55 ppm, which is 54% of its PEL. We also found hydrogen sulfide at levels ranging from 1.91 to 5.01 ppm, for an average of 3.46 ppm, which is 35% of its PEL. Their health risk at this area was proportional to the combination of exposure levels (34.6% + 54.1% = 88.7%). We recommended that the client continue to monitor its employees exposure to hydrogen sulfide and hydrogen cyanide.

Example Problem:

Employees are continuously exposed to the contaminant levels below. What percent of the mixture formula limit does the combination represent? Should we take action? You can use the signs and symptoms information in Appendix A in your considerations.

Chemical	Concentration (ppm)	PEL or TLV (ppm)
Acetic anhydride	2	C-5
Xylene	45	100
Heptane	190	400

2. Hazardous Waste Industry Approach

The problem with using the typical industrial hygiene approach at a hazardous waste site consists of its reliance on air sampling data from previous days. The episodic (variable) nature of our work means that the results of air samples collected last Tuesday poorly predict the exposures that we will experience next Thursday. That is why the hazardous waste industry focuses on the use of direct reading instruments.

For years, it was typical practice in our industry to collect a direct reading air measurement, and compare it to the exposure limit for the most restrictive compound that we thought was present. This procedure puts personnel in respirators when the contaminants are well below limit values. The authors' work teams use this procedure only when elevated exposures are unlikely.

Typical procedure in our industry today is to collect at least one direct reading measurement that provides information about every contaminant identified in the preliminary risk assessment (see Section III B and C). The results of those measurements are compared individually to the limit values for the compounds, and as a composite exposure using the ACGIH mixture formula.

3. Recommended Approach

The usual industry approach often results in the use of many different monitoring instruments, which consume much effort, money, and attention. Often, when compound-specific instruments are not available, teams upgrade or downgrade their levels of protection based on a single broad-spectrum instrument, like a total organic vapor monitor. The problem that occurs when this approach is used is that the teams must base their actions on the assumption that the reading consists either of 100% of the lowest exposure limit compound on the site, or of some fixed percentage (chosen based on "professional judgment") of that compound.

The authors suggest a modification of the usual industry approach. Industrial hygienists should:

- Use the techniques described in this course work book to limit the contaminants of concern to the shortest list possible.

- Review the list of contaminants and limit values to pick an action level that protects against the materials that are present on the site in greatest concentration

- Develop a strategy for deciding (based on an easy measurement) when to measure specifically for the compounds with low exposure limits to eliminate concern about exposure to them.

An example of a decision tree like that described above is shown below for work on a gasoline underground storage tank site where the benzene standard applies.

Example

TOV Reading	Action Taken
Bkgd - 2 ppm	Level D. Work may continue.
2 - 10 ppm	Level D. Collect benzene detector tubes.
10 - 500 ppm	Level C. Collect benzene detector tubes.
>500 ppm	Leave Area. Contact Industrial Hygiene.

Benzene Level	Action Taken
0 - 0.5 ppm	Level D. Work may continue.
0.5 - 10 ppm	Level C.
>10 ppm	Leave Area. Contact Industrial Hygiene.

Note that this example 1) assumes that level B is unavailable and 2) arbitrarily does not allow the use of air purifying respirators between 10 and 50 ppm, which the OSHA standard allows. The example shows how a team can measure the specific compound only when they have reason to suspect its presence. They can avoid exposures while performing their work without unnecessary hassle.

C. "Unknown" Sites

1. OSHA Standard Policy

Subparagraph (c)(5)(iii) of 29 CFR 1910.120, OSHA's standard for hazardous waste operations directs employers to provide a protective equipment ensemble equivalent to Level B during any entry into a site where the preliminary risk assessment has not fully characterized the hazards. Although this procedure is appropriate for initial entries (the subject of the paragraph in which the statement is made), at some sites the hazards will not be "fully characterized" until your work team's investigation has been over for several weeks. The authors feel that other approaches can produce adequate information and protection for projects that last a few days or weeks. The USEPA standard operating safety guideline for response to total vapor readings is presented below.

2. USEPA Standard Operating Safety Guidelines

Field work sometimes occurs on sites where the air contaminants are not fully characterized. In this situation, many work teams rely on USEPA's system for selecting level of protection based on the total vapor or gas concentration in these situations.

"Total atmospheric vapor or gas concentration" means the read-out, in ppm, of a direct reading instrument such as an OVA FID or an Hnu PID. These meters do not indicate the actual concentration of total vapor or gas present, only an instrumental response proportional to it. Accurate concentration readings can be obtained only by calibrating the instrument to the single substance being measured. The instrument sensitivity (span) of the meters is set upon calibration as directed by the manufacturers.

a. Factors For Consideration

The IH must consider the following factors before selecting a level of protection based on the total vapor or gas reading.

- o The operation and limitations of the monitoring instruments must be recognized and understood. The instruments do not respond to all substances or respond identically to the same substance.
- o Some gases are not detected by these meters (e.g., phosgene, arsine, cyanides, chlorine).
- o Explosives, flammable materials, oxygen deficiency, liquid/solid particles, or liquid or solid chemicals are not detected.
- o Airborne contaminants must be identified rapidly so that action levels based on specific exposure limits can be used.
- o Vapors or gases with a very low TLV or IDLH could be present. This procedure may not indicate unsafe conditions.
- o The IH must conscientiously balance the risk of each task against the value of the information to be obtained.
- o Any potential for suspect carcinogens or substances that are toxic or highly corrosive to skin to be present requires an evaluation of these factors.
- o The exposure potential of the task must be evaluated. Level C protection may be adequate for inspecting a site on which active tasks would require a higher level of protection.

If these conditions are present, total vapor or gas readings can yield a false sense of security. Teams should not use total vapor or gas concentration to select level of protection without industrial hygiene approval.

b. Level D Protection (only at background)

The USEPA system allows the use of level D protection (the only level without respiratory protection) only in the absence of any indication of air contaminants.

c. Level C Protection (Up to 5 ppm above background)

When the air contaminants have not been completely characterized, and in the absence of odors or other indications of the presence of chemical contaminants, level C protection (coveralls and an air-purifying respirator) can be selected for total vapor or gas readings up to 5 ppm above background as measured in the breathing zone with a meter like the PID (11.7 eV) or FID instrument.

EPA and NIOSH documents describe several restrictions on use of level C. If any of those conditions apply, use of level C is prohibited. Unanticipated transient excursions may unexpectedly increase the concentrations in the environment above the limits of air-purifying devices. Potential sudden releases from the work in progress may require level B protection, although ambient levels are low.

d. Level B Protection (5 ppm to 500 ppm above background)

When the air contaminants have not been completely characterized, and in the absence of odors or other indications of the presence of chemical contaminants, level B protection can be selected for readings between 5 and 500 ppm above background as measured in the breathing zone.

Consider upgrading from Level B to Level A at 500 ppm. Because organic compounds are unlikely to condense on the skin at concentrations below 500 ppm, this level helps protect the skin until the constituents can be identified and measured. Although Level B protection is adequate for many substances at levels higher than 500 ppm, use this limit as a decision point for careful evaluation of the risks associated with higher concentrations. Consider the factors listed in Section 5.1.

e. Level A Protection (500 ppm to 1000 ppm above background)

When the air contaminants have not been completely characterized, and in the absence of odors or other indications of the presence of chemical contaminants, level A protection can be selected for readings greater than 500 ppm and less than 1,000 ppm as measured in the breathing zone on a PID (11.7 eV) or FID instrument.

Although Level A provides protection against toxic effects at levels greater than 1,000 ppm for most substances, an operational restriction of 1,000 ppm provides a warning flag to:

- Evaluate the need to enter environments with unknown concentrations greater than 1,000 ppm.
- Identify the specific constituents contributing to the total concentration and their associated toxic properties.
- Evaluate the calibration and/or sensitivity error associated with the instrument(s).
- Evaluate instrument sensitivity to wind velocity, humidity temperature, etc.
- Consider the possibility that **an explosion hazard may also be present, particularly in confined spaces.**

Ambient air concentrations approaching 500 ppm are rarely found on hazardous waste projects. High concentrations have been seen in confined spaces, when containers were being opened, when personnel were working in the spilled contaminants, or when organic vapors/gases were released in transportation accidents. A decision to require Level A protection should also consider the negative aspects: higher probability of accidents due to cumbersome equipment, and what is most important, the physical stress caused by heat buildup in fully encapsulating suits.

V. Incorporating Instrument Response In Action Levels

A. Physical and Chemical Principles

Meter units

The instruments most commonly used to monitor air at hazardous waste sites sense organic vapors using photoionization detectors (PIDs) or flame ionization detector (FIDs). The choice between these two starts with the question, "Which of these instruments can detect the contaminants of concern?" The PID usually produces a satisfactory response if the energy rating of the meter's lamp (in electron volts) is greater than the Ionization potential (i.p. also in electron volts) of the contaminants of concern. The FID usually produces a satisfactory response if; the contaminants of concern will burn in a hydrogen flame, contain organic carbon, and do not contain too many atoms (like sulfur and bromine) that "quench" free radicals. Most common organic vapors produce a response on both types of detector.

The relative response of these detectors to the contaminants of concern must next be considered. The relative sensitivity is the degree of response that a given concentration of the contaminant in question produces on the meter, when compared to the same concentration of the material for which the instrument was calibrated (PIDs are usually calibrated to isobutylene. FIDs are usually calibrated to methane.). This question needs to be evaluated for each significant contaminant of concern, because this factor allows the industrial hygienist to estimate the concentration of the contaminants based on the reading on the instrument. The response of PID instruments to a contaminant varies with the lamp energy of the meter. A typical meter with an 11.7 eV lamp produces a much greater response for a material with an i.p. of 11 eV than the same meter with a 10.2 eV lamp, but only half as much response for a material that has an i.p. of 10.0.

B. Applying the Principles

We said in Section IV A that an action level (typically one-half the PEL/TLV, as read on the meter), will be used for upgrade from Level D to Level C (or B, if air-purifying respirators will not protect) and another (typically one-third of the IDLH, as read on the meter) is used for upgrade from Level C to B. The industrial hygienist can use the relative sensitivity of the meter to establish action limits in the units in which the meter displays. He or she simply multiplies the action limit for the contaminant of concern by the sensitivity to determine a reading that corresponds to the action level.

C. AxonMetr Spreadsheet

The floppy diskette enclosed with this book contains four spreadsheet templates designed to run on Lotus, Quattro Pro, or Excel. One of these templates, called AxonMetr, helps you to easily incorporate the relative sensitivity of PID and FID instruments into your health and safety decisions.

The columns in the Axonmetr template are as follows:

Col. A	Name of volatile compound
Col. B	PEL or TLV, which ever is lower
Col. C	IDLH level, as set by NIOSH
Col. D	Level to which upgrade occurs, derived from NIOSH
Col. E	Ionization potential, mostly from vendor information sheets.
Col. F	Response factor for a 10.2 eV PID instrument.
Col. G	The product of one-half of the PEL or TLV and the response factor
Col. H	The product of one-third of the IDLH and the response factor
Col. I	The product of one-half of the IDLH and the response factor
Col. J	Response factor for a typical FID instrument.
Col. K	The product of one-half of the PEL or TLV and the response factor
Col. L	The product of one-third of the IDLH and the response factor
Col. M	The product of one-half of the IDLH and the response factor

A portion of the content of the AxonMetr template is presented as Exhibit D to this manual. Although the AxonMetr data is presented on a spreadsheet, the template does not perform active calculations on data that you enter. Putting it in a spreadsheet helped us provide the data to you with the other products that are the subject of this course. You would use this spreadsheet by looking up the materials of concern in the table to verify that each provides an adequate response, and then comparing the action levels on the table to choose the instrument reading at which you will take action.

Example Problem:

If cresol (TLV = 5 ppm, i.p. = 9.0 eV) is the only volatile compound on the site, what meter would you use for monitoring? What action level would you use for upgrade from level D? What action level would you use for upgrade from level C?

VI. Action Levels for Non-Volatiles in Soil

A. Physical and Chemical Principles

1. Particulates that "Travel with Soil Dust"

The presence of contaminants in soil or water does not always imply an inhalation hazard. Substances with low vapor pressures usually disperse only as mists or dusts. One result of this observation is that non-volatile materials in water will not enter the air unless the water itself enters the air as mist. For example, PCBs, which have very low vapor pressures, may pose an inhalation hazard by piggybacking on airborne dust. If you apply water to the soil to keep the dust down, the PCB inhalation hazard would also be significantly reduced.

2. Limitations of Procedure

Working in locations where solid or liquid contaminants are present in soil requires special planning. The IH may compare the concentration of total or respirable dust in the air to the established exposure limit by the method below. This method applies only to contaminants (for example, metals, radionuclides, salts, and non-volatile organics) which travel through air <u>with</u> the soil particles. Don't use it for:

- volatile organic or inorganic compounds.
- asbestos fibers
- agents for which no allowable exposure limit has been set
- solid materials not intimately associated with the soil (for example; freshly generated lead fume)

3. No Contaminant of Concern

For job-sites where there is no contaminant of concern, prudent contractors will keep exposure to respirable nuisance dusts below the OSHA PEL of 5 mg/m^3. This implies that work teams will don respirators when the concentration of respirable dust exceeds 2.5 mg/m^3.

B. Calculating Equivalent Dust Concentration

1. One Contaminant of Concern

For job-sites with a single contaminant of concern (such as cadmium), the following formula can be used to establish an exposure limit.

$$EL_{mix} = \frac{(EL\ mg/m^3)}{(conc\ g/g)(Safety\ Factor)} = \frac{(10^6\ mg/Kg)\ (EL\ mg/m^3)}{(conc\ mg/Kg)(Safety\ Factor)}$$

Where:

EL_{mix}: Air concentration of total dust at which the contaminants of concern would be at their established exposure limit.

EL: Exposure limit of the contaminant of concern, e.g., its PEL, REL, or TLV, whichever is lower, in mg/m^3

10^6: Conversion factor

conc: Soil concentration of the contaminant of concern in mg/kg. Start with the highest value in the data you have.

Safety Factor: A number between one and ten used to account for the degree of confidence you have in your concentration information.

Choose a safety factor based on your judgment of whether:

- o The concentration of the contaminant in the airborne dust is the same as its concentration in soil.
- o The soil concentration data depicts a representative or worst case.
- o The monitoring instrument used accurately reports the concentration of dust in air (a respirable dust monitor will under-report the concentration of total dust in air).

If you're confident that the data represent site conditions well, use a safety factor of 2. If you have some confidence, use 4. If you have no confidence, use 10 or 20. If you have no information about the quality of the concentration information, use 10 all of the time.

Example:

Lead in soil at 2,000 ppm. PEL = 0.05 mg/m^3

$$\textbf{Exposure Limit, } EL_{mix} = \frac{(10^6 \text{ mg/Kg})(.05 \text{ mg/m}^3)}{(2000 \text{ mg/Kg})(4)} = 6.25 \text{ mg/m}^3$$

In the example, lead at 2,000 mg/Kg (ppm) results in a dust exposure limit of 6.25 mg/m^3. When the atmosphere contains 6.25 mg/m^3 of total dust, it contains no more than 0.05 mg/m^3 of lead, its PEL. Respiratory protection would be recommended at respirable dust levels of 2.5 mg/m^3, one half of the OSHA PEL for dust. Lead would not present a health problem in this case. (See Subsection D)

2. Several Contaminants with a Collective Exposure Limit

For sites contaminated with chemicals that have a collective limit [for example, polynuclear aromatic hydrocarbons (PNAs)], the sum of the total contaminants found in soils should be used to establish soil concentration. The equation below can be used to establish the exposure limit:

$$EL_{mix} = \frac{(EL^{©} \text{ mg/m}^3)}{(\sum \text{conc mg/Kg})(\text{Safety Factor})} = \frac{(10^6 \text{ mg/Kg})(EL^{©} \text{ mg/m}^3)}{(\sum \text{conc mg/Kg})(\text{Safety Factor})}$$

Where:

EL(c): Collective exposure limit, e.g., the TLV or PEL, whichever is lower, for the group as a whole, in mg/m^3.

$\sum$conc: Sum of the soil concentrations of the contaminants of concern in mg/Kg

All other terms are defined as in Section 7.2.

Example:

Total polycyclic aromatic hydrocarbon concentration in soil is 4,500 mg/Kg, EL© = 0.2 mg/m³.

$$EL_{mix} = \frac{(10^6\ mg/Kg)\ (0.2\ mg/m^3)}{(4{,}500\ mg/Kg)\ (4)} = 11\ mg/m^3$$

Again, the nuisance dust TLV would apply before the exposure limit for PNAs was reached. Respiratory protection would be recommended at one half the dust limit or 2.5 mg/m³. A full face respirator with a high efficiency and organic vapor filter would be appropriate for this exposure.

3. Several Contaminants with Individual Exposure Limits

We can adapt the previous equation for use with aerosols containing more than one contaminant of concern by substituting the term (airborne dust level / mass fraction of contaminant) for the contaminant level in the ACGIH mixture formula. This produces a formula that looks like:

$$\%\ allowed = \sum(Dust\ Level * (Conc_n / Limit_n)$$

Solve the equation for the airborne dust level at which the formula shows exposure at 100% of allowable limits for the mixture.

$$1 = Dust\ Level * \sum(Conc_n / Limit_n)$$

Then add the safety factor and the unit conversion. The equation becomes:

$$EL_{mix} = \frac{(10^6\ mg/Kg)}{[\sum(conc_n / ELn)]\ (Safety\ Factor)}$$

Where:

EL_n = Established exposure limit for each contaminant of concern in the soil.

The remaining terms are defined as in Sections 7.2 and 7.3. One to apply the formula above is through use of a paper spreadsheet like the example shown below.

Contaminant	OSHA PEL	ACGIH TLV	Soil Conc	$Conc_n/EL_n$
Arsenic	0.01*	0.20	1,500	150,000
Cadmium	0.002*	0.05	80	40,000
Chromium	0.10	0.05*	1,000	20,000
Nickel	1.00	1.00*	500	500
Lead	0.05*	0.15	2,500	50,000
Total				260,500

* This limit was used as EL_n

$$EL_{mix} = \frac{(10^6\ mg/Kg)}{(260{,}500)\ (4)} = 0.96\ mg/m^3$$

An exposure limit of 1.0 mg/m³ would be established for this soil. Respiratory protection would be recommended for any activity that produces dust, for windy conditions, or when dust is visible See Section 9.1.

C. Use of the DustLevl Spreadsheet Template

We find this approach so useful that we do these calculations several times a week. We simplified the work involved by placing the calculations on a spreadsheet template we call DUSTLEVL.WQ2. A print-out that shows how the spreadsheet template works appears as Exhibit E. The spreadsheet template, itself, is provided on the 3½" disk that accompanies this work book.

This section describes procedures for use of that template.

1. Running the DustLevl Template

1. Enter the spreadsheet that resides on your computer.

2. Call the template into the work space. (Its QuattroPro 5 name is DustLevl.WQ2. Its Lotus name is DustLevl.WK1. Its Excel name is DustLevl.XLS.)

3. Check that the main screen (the area above the explanations) contains the contaminants you want to include. Import rows of information from the storage space below the explanations if you need to. Don't worry about the presence in the template of extra chemicals, but calculations below the explanations don't participate in mixture formula summation.)

4. Enter the Safety Factor in block E4. The Safety Factor should incorporate the factors described in Section VI B 1.

5. Pre-set the concentrations (column C) to "1E-09" using the copy function. This step erases soil levels from other sites.

6. Enter the concentration for each contaminant of interest (if you have several values for the same material, enter the highest) in site soil.

7. Because these spreadsheets recalculate continuously, the answers will appear on the right edge and bottom of the spreadsheet as soon as you finish entering data.

2. Interpreting the DustLevl Template Results

Location	Nature and Use of Data
Column D	Concentration of dust in air at which, if you selected the safety factor well, the single contaminant is at its exposure limit. Use as an action level if this is the one compound of concern.
Column E	"Dust Quotient." Used for subsequent determinations
Block E46	Concentration of dust in air at which, if you selected the safety factor well, the contaminant mixture is at its exposure limit. Use directly as an action level for the mixture as a whole.
Column F	The predicted concentration of the contaminant of interest, as a fraction of its PEL or TLV, when the total dust-in-air concentration is 5 mg/m^3.

The Quattro Pro and Excel versions of the templates also produce a graph that shows the airborne concentration of the individual contaminants and the mixture, as a proportion of their PELs or TLVs, when the dust level is at 5 mg/m^3.

Example Problem:

Your work teams intend to build a road through a site on which the surface soil contains the following contaminants: Acenaphthene at 255 mg/kg, Benzo(a)Pyrene at 3,500 μg/kg, Benzanthracene at 23 ppm, Benzene at 3.5 ppm, Cadmium at 16 ppm, Dichloromethane at 0.3 mg/kg, Lead at 32 mg/g, Mercury at 25 ppm, Strontium 90 at 25 μCi/g, and Vinyl Chloride at 0.3 μg/g. After you run the spreadsheets, answer the following questions:

1. Which compounds can you ignore from an employee health perspective?
2. Which compounds will dominate the response of total organic vapor monitors?
3. Which compounds will drive your upgrades or downgrades of protective equipment?
4. What upgrades or downgrades will you specify?
5. If compliance with the limits is your goal, will those action levels result in donning the respirators too early?
6. How does rainfall affect your action levels?

D. IH Applications of Equivalent Dust Concentration

1. Hazard Assessment

The usual output of this analysis is the total concentration of dust in air that would correspond to an exposure to toxic materials at their exposure limits. The way we use the results of this analysis is described in the following section on measurement.

2. Determining Particulate Concentrations

If particulate exposure is a concern, monitor airborne concentrations with a respirable dust monitor like the MIE Miniram or collect filter samples for laboratory analysis with an air sampling pump. Sample with an air pump during initial stages of all site tasks when the crew will remain on site for a longer time than would be consumed by laboratory analysis, e.g., for field operations lasting more than a week. Respirable dust particles are generally not visible to the naked eye, but total airborne dust clouds are often visible (when the cloud is large) at concentrations of 2 mg/m^3.

If you calculate an exposure limit of 1 mg/m^3 or less for a dust, always wear respiratory protection unless air monitoring results show an exposure below acceptable limits. For any soil or dust with an exposure limit of 2 mg/m^3 or more, respiratory protection is generally not necessary unless airborne dusts are produced through mechanical means, or wind generated, or airborne dusts become visible in the breathing zone.

3. Simultaneous Exposure to Aerosols and Vapors or Asbestos

When the contaminants of concern at a site include those for which this method applies (metals, salts, etc.) and those for which it does not (gases, vapors, asbestos, etc.), exposure must be separately assessed by the methods appropriate for each contaminant. In some circumstances, it may be appropriate to add the exposures from the different classes of material. See Section 4.3.

VII. Action Levels for Volatiles in Water

A. Physical and Chemical Principles Involved

Gas and vapor concentrations can be measured on site by the photoionization, flame ionization, infrared spectroscopy, or other techniques. The levels can also be estimated before site work by the following procedures.

B. Calculating Saturation Vapor Pressure

1. Pressure Over Pure Liquid

Contaminants that have high vapor pressures are more likely to be present in the atmosphere as vapors. You can estimate your potential exposure to volatile contaminants by comparing the soil or water concentration and vapor pressure to the exposure limit. The concentration of a vapor in a work space can never exceed its concentration at saturation at its source. Find the published saturation vapor pressure up in a standard reference like the CRC Handbook of Chemistry and Physics or Lange's Handbook of Chemistry. If the vapor pressure [P^v (in torr or mm Hg) times 1316 ppm/torr (1,000,000 ppm/atm ÷ 760 torr/atm)] is lower than the established exposure limit, then the air you breathe can never contain vapor above that limit.

Examples

Is P^v * 1,316 ppm/torr < PEL ?

You are developing a health and safety plan. Isophorone is present in the soil at high concentrations. You can compare the saturation vapor pressure (0.4 mm Hg) to the OSHA PEL (5 ppm) in one equation as follows:

$$\text{Exp} = \frac{0.4 \text{ torr} * 1{,}000{,}000 \text{ ppm/atm}}{5 \text{ ppm} * 760 \text{ torr/atm}} = 105 \text{ times the PEL}$$

PCBs are present in the soil at the site at high concentrations. You can compare the saturation vapor pressure (7.7×10^{-5} mm Hg) to the OSHA PEL after converting the mass limit (0.5 mg/m^3) value to parts per million using the molecular weight.

$$\text{PEL} = 0.5 \text{ mg/m}^3 * 24.45 \div 328 = 0.037 \text{ ppm}$$

$$\text{Exp} = \frac{7.7 \times 10^{-5} * 1{,}000{,}000}{0.037 \text{ ppm} * 760} = 2.7 \text{ times the PEL}$$

These results suggest that isophorone exposure may be a problem at this site, especially if weather reduces dispersion by wind, and that PCB vapor exposure can be a problem in confined spaces.

2. Pressure Over Solutions Using Raoult's Law

One way to estimate the maximum possible concentration in the air over contaminated water is by using Raoult's Law to find the saturation vapor pressure. You need a vapor that is very water-soluble and its concentration. Raoult's law relates vapor pressure to concentration as follows:

$$(P^*) = \text{Pure Liquid Vapor Pressure } (P^v) * \text{Concentration } (X)$$

$$\frac{Vp \times 10^6}{760}$$

(11.8)

The restrictions on the use of Raoult's law are as follows:

- The concentration, (X), must be stated in mole fraction which is (in water) roughly the molar strength divided by 55.5 (the number of moles in a liter of water).

- Raoult's law is more accurate for stronger (> 0.5 mol/liter) solutions.

- Raoult's law is more accurate for more soluble (> 1 mol/liter) contaminants.

- Water forms low - boiling azeotropes with many compounds, so that Raoult's Law may underestimate the concentration.

Reminder: The concentration in moles / liter equals the number of grams of chemical in a liter of water divided by its molecular weight. For benzene, one mole / liter equals 78,000 milligrams per liter.

Example
You are developing a health and safety plan. Methyl ethyl ketone is present in surface water at 5,000 mg/l. Because it is soluble in water at 3 moles / liter, you choose Raoult's law. You calculate the solution vapor pressure from the published saturation vapor pressure (90.6 mm Hg) and molecular weight (72.1 g/mol) as follows:

$$P^{v} = \frac{90.6 \text{ mm Hg} \times 5 \text{ g/l}}{72.1 \text{ g/mol} \times 55.5 \text{ mol/l}} = 0.113 \text{ torr} \times \frac{1.316 \text{ ppm}}{\text{torr}} = 148 \text{ ppm}$$

3. Pressure Over Solutions Using Henry's Law

If a less-soluble contaminant vapor arises from ground water, and you know its concentration, you can estimate its maximum possible concentration in the air by using Henry's Law to find the saturation vapor pressure. Henry's law relates vapor pressure to concentration as follows:

(P*) = Henry's Law Constant (H^{v}) * Concentration (X)

Henry's Law constants are published in environmental sources like the <u>Superfund Public Health Evaluation Manual</u> (Note: No longer in print) or Howard's <u>Handbook of Environmental Fate and Exposure Data</u>. These sources often provide the constant in inconvenient units like atm-m^3/mole. You can either adjust the units in which you enter data, or multiply the vapor pressure you calculate by 1,000,000 ppm/atm to find the highest possible concentration. If you use these constants the way you find them in the literature, remember that (at standard temperature and pressure) there are about 41 moles of gas in a cubic meter. You can derive a decent estimate of the constant for compounds with limited (less than 1 mole per liter) solubility in water by dividing the solubility of the compound in water into its pure state vapor pressure.

Example

You are developing a health and safety plan. Methyl chloroform is present in ground water at 6 ppm. Because the solubility is low, you select Henry's law. You calculate the constant from the published saturation vapor pressure (124 mm Hg) and water solubility (4,400 mg/l) as follows:

$$H^{v} = \frac{124 \text{ mm Hg}}{4{,}400 \text{ mg/l}} = \frac{0.028 \text{ torr}}{\text{mg / l}} \times \frac{1.316 \text{ ppm}}{\text{torr}} = \frac{37 \text{ ppm}}{\text{mg / l}}$$

You can use this constant to calculate the vapor pressure as follows:

$$P^{*} = 6 \text{ mg/l} * 37 \text{ ppm / (mg/l)} = 222 \text{ ppm} \quad \text{(64\% of the OSHA PEL)}$$

4. Using Hank's Short - Cut

You can derive the estimate of the Henry's Law constant in the same equation in which you calculate the concentration of interest. This calculation has the added advantage in giving you the constant in exactly the units you prefer.

Examples

You are developing a health and safety plan. Methyl chloroform is present in ground water at 6 ppm. You can calculate the calculate the vapor pressure over the mixture using the published saturation vapor pressure (124 mm Hg) and water solubility (4,400 mg/l) in one equation without deriving a Henry's Law constant as follows:

$$P^{*} = \frac{6 \text{ mg/l} * 124 \text{ torr} * 1{,}000{,}000 \text{ ppm/atm}}{4{,}400 \text{ mg/l} \quad * \quad 760 \text{ torr/atm}} = 222 \text{ ppm}$$

$\frac{3.2 \text{ mg/l} \times 766 \times 10^6}{5710 \quad 760} = 565$ + TLV

$\frac{.015 \times 297/760}{2100}$ = 5.8 = 2.8/4 + TLV

The vapor pressures derived with the equations above are <u>maxima</u> above which employee exposures can <u>never</u> rise, unless the analytical data are wrong or the water is heated. If the concentrations you calculate are well below the exposure limits for the chemicals of concern, your exposure will be also. The result above, 222 ppm, is far enough below the compound's PEL of 350 ppm so that you would not need to monitor for methyl chloroform. If your calculations indicate an exposure potential at saturation, you will need to monitor your breathing air. Of course, you should make such decisions only on the basis of reliable contaminant data. (Assessing the quality of such data, by the way, will always be a judgment call.) Volatile organic compounds, however, are <u>usually</u> present in the breathing air (in ppm by volume) below their concentrations (in ppm by weight) in the soil or water from which they originate.

Example Problems:

You want to discharge the water from a pump test to the facility's waste water treatment lagoon. The water contains ethyl chloride (TLV = 1,000 ppm, P^{sat} = 766 torr, C^{sat} = 5,710 mg/l) at 3,200 μg/l. Can this water create an exposure above the TLV? What factors would increase or decrease the potential hazard?

You learn that the water also contains carbon disulfide (TLV = 4 ppm, P^{sat} = 297 torr, C^{sat} = 2,100 mg/l) at 15 μg/l. How does this observation change your previous answers? What actions are appropriate?

C. Use of Vapor Template on Spreadsheet

We find this approach so useful that we do these calculations at least once a week. We simplified the work involved by placing the calculations on a spreadsheet template we call VAPOR.WQ2. The template uses (the Hank's short-cut version of) Henry's law to calculate the vapor pressure over contaminated water. We shoe-horn more soluble materials for which Raoult's law would be more appropriate into the Henry's Law equation by entering impossible water solubilities (such as 3,000,000 milligrams per liter for acetone) to force the equation to yield useful results.

We include a print-out that shows how the spreadsheet template, VAPOR.WQ2, appears as Exhibit F to this course manual. The spreadsheet template, itself, is provided on the 3½" disk that accompanies this work book.

This section describes procedures for use of that template.

1. Running the Vapor Template

1. Enter the spreadsheet that resides on your computer.

2. Call the template into the work space. (Its QuattroPro 5 name is Vapor.WQ2. Its Lotus name is Vapor.WK1. Its Excel name is Vapor.XLS.)

3. Check that the main screen (the area above the explanations) contains the contaminants you want to include. Import rows of information from the storage space below the explanations if you need to. Extra chemicals don't harm the spreadsheet, but calculations below the explanations don't participate in mixture formula summation.

4. Pre-set the concentrations (column B) to "1E-09" using the copy function.

5. Enter the concentration (if you have several values, enter the highest) in site water for each contaminant of interest.

6. Because these spreadsheets recalculate continuously, the answers will appear on the right edge and bottom of the spreadsheet as soon as you finish entering data.

2. Interpreting the Vapor Template Results

The template, as we have loaded it for you, produces results that appear in the following blocks on the spreadsheet. If you enter new compounds, or extra columns of data (you might be one of those people who like Chem Abstracts numbers in your tables), the results will, of course, move.

Location	Nature and Use of Data
Column F	Saturation concentration in parts per million. Used for subsequent determinations. Includes a test that prevents display of airborne concentrations above saturation for pure liquid.
Block F41	Sum of the saturation vapor concentrations. Used for subsequent determinations
Column G	Relative contribution by this compound to total vapor. Should parallel the percentage in your field measurements. Use to select monitoring equipment, not instead of measurement.
Column H	Percent of allowable limit represented by the greater of the value in column F or the saturation vapor pressure. If this value is 1 to 10%, the compound is a problem only as part of the mixture toxicity. If it is 100 to 400%, the compound could present a hazard in confined spaces. If it is over 5,000%, field exposure could be significant.
Block H42	This block presents the summation of exposures as a fraction of the mixture exposure limit, assuming both saturation conditions and the ACGIH mixture formula. If this value is below 1, a exposure above the limit values is not possible.

The Quattro Pro and Excel versions of this template also produce a graph that shows the airborne concentration of the individual contaminants, as a fraction of their PELs or TLVs, and as a fraction of the total vapor expected.

Example Problem

Your work teams are about to install monitoring wells on a site on which the water contains the following contaminants: Benzene at 3.5 ppm, Dichloromethane at 0.3 mg/l, 1,1-Dichloroethylene at 57 ppb, Lead at 32 mg/l, Mercury at 25 ppm, Styrene at 456 ppm, and Vinyl Chloride at 0.3 μg/l. After you run the spreadsheet, answer the following questions:

1. Which compounds can you ignore from an employee health perspective?
2. Which compounds will dominate the response of total organic vapor monitors?
3. Which compounds will drive your upgrades or downgrades of protective equipment?
4. What upgrades or downgrades will you specify?
5. If compliance with the limits is your goal, will those action levels result in donning the respirators too early?

Example Problem

The work teams reveal a hitherto unsuspected aquifer at intermediate depth. The lab reports the following contaminant levels in the water from this new aquifer: Acetone at 6050 ppb, Benzene at 1500 ppb, Carbon Disulfide at 4 ppb, Chlorobenzene at 3.8 ppb, 1,2-Dichlorobenzene at 5 ppb, 1,4-Dichlorobenzene at 9 ppb, 1,2 Dichloroethane at 150 ppb, Ethyl Benzene at 3000 ppb, and Toluene at 12000 ppb. After you run the spreadsheet, answer the questions above.

Use same techn to calculate LEL (100%) of a mixture ?

VIII. Establishing Exposure Limits for Volatiles in Soil

A. Physical and Chemical Principles

Volatile chemicals tend to diffuse from spaces in which they are at high concentration into spaces in which they are at low concentration. Volatile chemicals in the soil at a hazardous waste site, therefore, tend to constantly enter the air over the site.

The measurement procedure we described in Section VII A is, of course, applicable to volatiles in soil. The pure liquid vapor pressure procedure we described in Section VII B 1 is also applicable. Section VIII B describes the modifications we must make to apply the Henry's Law approach described in Section VII B 2 for volatiles in soil.

B. An Analog of Henry's Law for Volatiles in Soil

The rate at which volatile chemicals from site soil enter the air at the site depends on the chemical, its concentration, the moisture in the soil, the clay or organic carbon fractions (f_{oc}) in the soil itself, the pore size or volume in the soil, temperature, and wind speed. The organic carbon in the site soil is the most important "sink" for organic compounds in soil.

Because the approach we described in Section VII B 2 allows us to evaluate vapor concentrations in air when we know the concentrations in water, we can take advantage of models that predict the partition of organic compounds between the soil and ground water. Donald MacKay's 1991 book Multimedia Environmental Models says that, at equilibrium, *the fugacity* of a material (its energy of state reported in units of pressure) will be equal in all media that are in contact. He then provides formulae for fugacity (f) of a chemical in air, water, and soil as follows:

$$f_{air} = C_{air} * R * T$$

$$f_{water} = C_{water} * H \implies C_{water} * P^{sat} / C^{sat}$$

$$f_{soil} = C_{soil} * H / (f_{oc} * K_{oc} * \varrho_{soil})$$

Because, at equilibrium, all fugacities are equal, the air concentration can be calculated by:

$$C_{air} = (C_{soil} * P^{sat}) / (C^{sat} * f_{oc} * K_{oc} * \varrho_{soil} * R * T)$$

When we convert the SI units assumed in this equation to the units that you will probably use, and assume ambient temperatures, the equation becomes:

$$C_{air} = (1{,}316\ C_{soil} * P^{sat}) / (C^{sat} * f_{oc} * K_{oc})$$

Where the units are as follows:

P^{sat}	Saturation vapor pressure, torr or mm Hg *Found in chemical references, like those listed in the bibliography*
C^{sat}	Saturation water solubility, milligrams per liter *Found in chemical references, like those listed in the bibliography*
C_{air}	Concentration in air, parts per million by volume *The result for which you perform these calculations*
C_{soil}	Concentration in soil, milligrams per kilogram *A site parameter, provided by previous laboratory analysis*
f_{oc}	Organic carbon content, dimensionless ratio *Provided by laboratory analysis or from soil science references*
K_{oc}	Organic carbon partition coefficient, dimensionless ratio *Found in risk assessment references, like those listed in the bibliography*

Because this approach calculates air concentration at saturation, it is conservative for soil just like our approach was for water. If this calculation says that you do not need to worry about a chemical, you would have a high degree of confidence in that conclusion.

C. Use of SoilVapr Template on Spreadsheet

Because this calculation involves six values and several opportunities to make a mistake involving unit conversions, the authors simplified the work involved by placing the calculations on a spreadsheet template we call SOILVAPR.WQ2. A print-out that shows how the spreadsheet template, VAPOR.WQ2, works appears as Exhibit G. The spreadsheet template, itself, is provided on the 3½" disk that accompanies this work book.

This section describes procedures for use of that template.

1. Running the SoilVapr Template

1. Enter the spreadsheet that resides on your computer.
2. Call the template into the work space. (Its QuattroPro 5 name is SoilVapr.WQ2. Its Lotus name is SoilVapr.WK1. Its Excel name is SoilVapr.XLS.)
3. Check that the main screen (the area above the explanations) contains the contaminants you want to include. Import rows of information from the storage space below the explanations if you must. Extra chemicals won't hurt the spreadsheet, but calculations below the explanations don't participate in mixture formula summation.
4. Enter the organic carbon fraction for your soil in block H2. The value, 0.02 has been pre-entered, but this value will exaggerate vapor exposures from some soils.
5. Pre-set the concentrations (column B) to "1E-09" using the copy function.
6. Enter the concentration (if you have several values, enter the highest) in soil for each contaminant of interest.
7. Because these spreadsheets recalculate continuously, the answers will appear on the right edge of the spreadsheet as soon as you finish entering data.

2. Interpreting the SoilVapr Template Results

The template, as we have loaded it for you, produces results that appear in the following blocks on the spreadsheet. If you enter more compounds, or extra columns of data, the results will, of course, move.

Location	Nature and Use of Data
Column G	Saturation concentration in parts per million. Used for subsequent determinations. Includes a test that prevents display of a concentration higher than saturation for the pure liquid.
Block G41	Sum of the saturation vapor concentrations. Used for subsequent determinations
Column H	Relative contribution by this compound to total vapor. Should parallel the percentage in your field measurements. Use to select monitoring equipment, not instead of characterization.
Column I	Percent of allowable limit represented by the greater of the value in column G or the saturation vapor pressure. If this value is 1 to 10%, the compound is a problem only as part of the mixture toxicity. If it is 100 to 400%, the compound could present a hazard in confined spaces. If it is over 5,000%, field exposure could be significant.
Block I42	This block presents the summation of exposures as a fraction of the mixture exposure limit, assuming both saturation conditions and the ACGIH mixture formula. If this value is below 1, a exposure above the limits is impossible.

The Quattro Pro and Excel versions of this template also produce a graph that shows the airborne concentration of the individual contaminants, as a fraction of their PELs or TLVs, and as a fraction of the total vapor expected.

Example Problem

Your work teams are about to install monitoring wells on a site on which the surface soil contains the following contaminants: Benzene at 3.5 ppm, Dichloromethane at 0.3 mg/kg, 1,1-Dichloroethylene at 57 ppb, Lead at 32 mg/g, Mercury at 25 ppm, Styrene at 456 ppm, and Vinyl Chloride at 0.3 μg/g. Dust is well controlled by wet methods. Organic matter comprises 5% of the soil. After you run the spreadsheet, answer the following questions:

1. Which compounds can you ignore from an employee health perspective?
2. Which compounds will dominate the response of total organic vapor monitors?
3. Which compounds will drive your upgrades or downgrades of protective equipment?
4. What upgrades or downgrades will you specify?
5. If compliance with the limits is your goal, will those action levels result in donning the respirators too early?
6. Should you be concerned that the subsurface conditions will be worse than those you found on the surface?

3. Rules of Thumb

The Vapor and Soilvapr spreadsheets are not meant to substitute for industrial hygiene judgment. They are designed to yield relationships between contaminants that allow industrial hygienists to identify and measure the chemicals that are important for health concerns, and to identify those that can be ignored. Some rules of thumb that you might apply to the interpretation of the results of these calculations include:

- At least at the beginning of the analysis, enter the highest concentrations that have been reported to you. If the spreadsheet shows a low hazard at the high concentrations, no further analysis is required.

- When you have both soil and water concentration data, you should run both models to find the worst case prediction. In an ideal world these two ideal calculations would produce identical results. The predictions often vary by a factor of three.

- Remember that the purpose of this analysis is to help you select action levels and air monitoring equipment, not to provide an absolute prediction of the concentrations that field workers will face. If the data you used adequately represent the site conditions, your estimates will be much higher than the real exposures.

- The absolute contaminant concentration will decrease through diffusion as the point of measurement moves away from the source, but the relationship of the concentrations will remain unchanged. If the toluene is present in the air at ten times the concentration of benzene in the borehole, that ratio will also apply in the breathing zone.

- The relationship you calculated, however, only applies over soil or water at the concentrations you entered. Unless the concentrations of different compounds correlate well as location and source media change, the ratios of their air concentrations will vary.

- If you are concerned about variation between the ratios of vapor concentrations, try performing the Vapor or SoilVapr calculations on the concentrations from soil or water in a limited area.

- If the spreadsheet shows that a compound can not be present at more than 50% of its exposure limit, the compound is a problem only as part of the mixture toxicity.

- If the spreadsheet shows that a compound can be present at 100% to 400% of its exposure limit, the compound could present a hazard only in confined spaces.

- If the spreadsheet shows that a compound can be present at more than 5,000% of its exposure limit, it could present a hazard during field work.

- If the mixture formula result is lower than 100%, you may allow site work without air monitoring, if you believe that the concentrations the lab gave you actually represent the most contaminated material on the site. If you don't have that faith, then you may still use the contaminant ratios from your spreadsheet to select monitoring equipment.

Most readers will, at this point, have a reaction like, "How do I handle a result between these discontinuous ranges?". Our only response is; "Use industrial hygiene judgment. Most often, a compound that is in head space at 1,000% of the PEL will not reach the PEL in the breathing zone, but it can happen, with the right wind and weather conditions."

VIII. Conclusion

Health and safety are well served when complex risk-assessment decisions can be reduced to simple rules for actions in response to factors observable by the work team. This approach rests on the careful establishment of action levels at which evacuation or additional personal protection is required. These action levels are based upon allowable exposure limits for each contaminant and the response factors of the air monitoring instruments used.

The quantitative procedures described in this paper are intended to meet, for teams engaged in hazardous waste site investigation or remediation, the monitoring requirements of 29 CFR 1901.120 (c) OSHA's hazardous waste operations standard, and the "exposure determination" requirements single-substance OSHA standards, such as those for lead or benzene. OSHA has not commented on the acceptability of this approach.

Finally, remember that the quantitative techniques shown in this paper neither substitute for industrial hygiene judgment nor are they accurate estimates of exposure. They produce <u>over</u>estimates that allow health and safety personnel at hazardous waste sites to practice industrial hygiene roughly the way they would at a manufacturing facility.

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Consolidated toxic substance Registry
CD Rom

1800-668-4284
905-570-8094

800 668-4284

Canadian Center For
Occupational Health & Safety

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Acetaldehyde		C-25 ppm	2,000 ppm	0.066 ppm	Irritation, cough, CNS depression, pulmonary edema	10.21
Acetic acid		10 ppm	50 ppm	24.3 ppm	Pharyngeal edema, bronchitis, crying, irritation	10.66
Acetic anhydride		C-5 ppm	200 ppm	0.14 ppm	Pharyngeal irritation, cough, crying	10.00
Acetone		750 ppm	2,500 ppm	62 ppm	Irritated eyes, headache, dizziness	9.69
Acetonitrile		40 ppm	500 ppm	1,160 ppm	Asphyxia, nausea, chest pain, weakness	12.22
Acetophenone		10 ppm	NE	0.6 ppm	Irritated eyes, headache, dizziness, drowsiness	9.27
2-Acetylamino fluorene		NE	Carc.	NA	Reduced function of liver, & kidneys	NE
Acetylene		2,500 ppm	6,250 ppm	NA	Inert asphyxiant, flammable gas	11.4
Acetylsalicylic acid (Aspirin)		5 mg/m³	NE	Dust	Tinnitus, nausea & vomiting	Dust
Acrolein		0.1 ppm	2 ppm	2 ppm	Irritated eyes, mucous membrane, delayed pulmonary edema	10.10
Acrylamide (skin)		30 µg/m³	60 mg/m³	NA	Numb limbs, weakness sweaty hands, fatigue	9.5
Acrylic acid (skin)		2 ppm	NE	0.1 ppm	Eye watering, CNS stimulation, severe respiratory difficulties	10.9
Acrylonitrile		2 ppm	85 ppm	1.6 ppm	Headache, light head, sneezing	10.91
Adiponitrile (skin)		2 ppm	500 ppm	NE	Headache, light head, irritation burns eyes,	10.91

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Aldrin (skin)		250 µg/m³	25 mg/m³	<1 mg/m³	Headache, dizziness, nausea, jerks of limbs	NA
Allyl alcohol (skin)		2 ppm	20 ppm	1.4 ppm	Eye & bronchi irritation, pulmonary edema	9.67
Allyl chloride		1 ppm	250 ppm	0.5 ppm	Irritated eyes & nose, pulmonary edema, deep muscle pain	10.05
Allyl glycidyl ether (AGE)		5 ppm	50 ppm	<10 ppm	Irritated eyes & nose, narcosis	NA
Allyl propyl disulfide		2 ppm	NE	NA	Eye, nose, & throat irritation	NA
Aluminum (dust) (alkyls or soluble salts)		5 mg/m³ 2 mg/m³	NE	Dust	Coughing, spitting, pulmonary fibrosis	Dust
4-Aminodiphenyl		NE	Carc.	NE	Headache, dyspnea, weakness, urinary burning, lethargy	NA
2-Aminopyridine		0.5 ppm	5 ppm	NE	Headache, nausea, respiratory distress	8.00
Amitrole		200 µg/m³	NE	NA	Reduced thyroid function, goiter	NA
Ammonia		25 ppm	300 ppm	17 ppm	Irritated nose & throat, chest pain	10.18
Ammonium chloride (fume)		10 mg/m³	NE	NA	Mild irritation of eyes, nose & throat	NA
Ammonium sulfamate (dust)		5 mg/m³	1,500 mg/m³	no odor	Coughing	Dust
Amyl acetates (skin)		100 ppm	1,000 ppm	0.067 ppm	Irritated eyes & nose, narcosis banana odor	9.9

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Aniline (skin)		2 ppm	100 ppm	2.4 ppm	Headache, weakness, dyspnea	7.70
Anisidine (skin)		500 μg/m³	50 mg/m³	NA	Headache, dizziness, cyanosis,	7.44
Antimony compounds		500 μg/m³	50 mg/m³	Dust	Irritated nose, cough, headache, diarrhea	Dust
ANTU		300 μg/m³	100 mg/m³	NA	Vomit, dyspnea, cyanosis	NA
Arsenic, inorganic		10 μg/m³	5 mg/m³	Dust	Nasal ulcers, fever, bronchitis, melanosis, peripheral neuropathy	Dust
Arsine		0.05 ppm	3 ppm	<1 ppm	Headache, weakness, stomach & back pain, nausea	9.89
Asbestos		0.2 f/cc	Carc.	Dust	Dyspnea, restricted pulmonary function	Dust
Atrazine		5 mg/m³	NE	NA	Incoordination, dyspnea, convulsions	NA
Azinphos(-methyl) (skin)		200 μg/m³	10 mg/m³	NA	Small pupils, blurred vision runny nose, , headache, "tight" chest	NA
Barium (soluble)		500 μg/m³	50 mg/m³	NA	Muscle spasms, slow pulse, bronchial irritation	NA
Barium sulfate (dust)		5 mg/m³	NE	Dust	Few symptoms, chronic baritosis	Dust
Benomyl (dust)		5 mg/m³	NE	Dust	Dermatitis	Dust
Benzene		1 ppm	500 ppm	61 ppm	Eye & nose irritation, headache, giddiness, nausea, fatigue	9.25
Benzidine (skin)		NE	Carc.	NA	Hematuria, anemia, painful & irregular urination	NA
Benzoyl peroxide		5 mg/m³	1,500 mg/m³	no odor	Irritated skin & eyes, sensitization	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Benzyl acetate		10 ppm	>50 ppm	NA	Irritated skin & eyes, drowsiness muscle weakness	NA
Benzyl chloride		1 ppm	10 ppm	0.04 ppm	Irritated eyes, nose, irritable, headache	10.6
Beryllium		2 μg/m³	4 mg/m³	Dust	Respiratory symptoms, weakness, weight loss	Dust
Biphenyl		0.2 ppm	>100 mg/m³	0.01 ppm	Irritated eyes, nose, twitching, breathing difficulty	Dust
Bismuth telluride (dust)		5 mg/m³	NE	Dust	Decreased appetite, weakness, fever, foul breath, diarrhea	Dust
Boron oxides (includes borates)		1 mg/m³	NE	Dust	Nausea, conjunctivitis, diarrhea, skin rash	Dust
Boron tribromide		C-1 ppm	NE	NA	Irritant	9.7
Boron trifluoride		C-1 ppm	25 ppm	1.5 ppm	Burns eyes & skin, pneumonia	15.5
Bromacil		10 mg/m³	NE	NA	Weight loss & pallor	NA
Bromine		0.1 ppm	3 ppm	3.5 ppm	Dizziness, headache	10.55
Bromine pentafluoride		0.1 ppm	NE	NA	Coughing, nose bleed, dizziness	>15
Bromoform (skin)		0.5 ppm	850 ppm	530 ppm	Irritated eyes, CNS depression	10.51
Butadiene		2 ppm	5,000 ppm	0.45 ppm	Irritated eyes, light headedness, drowsiness	9.07
Butane		800 ppm	4,500 ppm	No odor	None	10.63
2-Butanone (MEK)		200 ppm	3,000 ppm	16 ppm	Irritated eyes, dizziness, vomiting	9.53

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
2-Butoxyethanol (skin)		25 ppm	700 ppm	0.10 ppm	Brown urine, irritated eyes	10.00
Butyl-acetate		200 ppm	10,000 ppm	0.3 ppm	Headache, drowsiness, dry & irritated eyes	10.0
Butyl acrylate		10 ppm	NE	0.009 ppm	Eye, nose & throat irritation narcosis	NA
n-Butyl alcohol (skin)		C-50 ppm	1,400 ppm	1.2 ppm	Irritated eyes, headache, vertigo, drowsiness, skin	10.04
Butyl alcohol (sec & tert)		100 ppm	1,600 ppm	3.2 ppm	Eye irritation, narcosis	10.10
Butylamine (skin)		C-5 ppm	300 ppm	0.1 ppm	Irritated eyes, headache, skin flush	8.71
Butyl chromate (skin)		C-100 µg/m³	15 mg/m³	NA	Lung & sinus cancer	NA
Butyl glycidyl ether		25 ppm	250 ppm	NA	Irritated eyes, sensitivity, narcosis	NA
n-Butyl lactate		5 ppm	NE	NA	eye, nose, & throat irritation, headache, drowsiness	NA
Butyl mercaptan		0.5 ppm	500 ppm	1 ppb	Narcosis, incoordination, lung irritation, weakness	9.14
Butylphenol (skin)		5 ppm	NE	NA	Contact dermatitis, depigmentation	NA
Butyltoluene		1 ppm	100 ppm	8 ppm	Dry nose, fast pulse eye, nose & throat irritation	8.28
Cadmium dust		5 µg/m³	9 mg/m³	Dust	Pulmonary edema, tight chest, chills	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Calcium carbonate		5 mg/m³	NE	Dust	Considered harmless	Dust
Calcium cyanamide		500 µg/m³	NE	Dust	Skin sensitization, flush & fever if with alcohol	Dust
Calcium hydroxide		5 mg/m³	250 mg/m³	Dust	Skin & eye irritation	Dust
Calcium oxide		2 mg/m³	25 mg/m³	Dust	Irritated eyes & lungs, pneumonia	Dust
Calcium silicate		5 mg/m³	NE	Dust	Eye, nose and throat irritation blurred vision	Dust
Calcium sulfate		5 mg/m³	NE	Dust	Nearly harmless	Dust
Camphor		2 ppm	200 mg/m³	0.08 ppm	Irritated eyes, nausea, irrationality, convulsions	8.76
Caprolactam (dust) (vapor)		1 mg/m³ 5 ppm	NE	Dust 0.065 ppm	Convulsions, salivation, large pupils	Dust NA
Captafol (skin)		100 µg/m³	NE	NA	Occupational dermatitis sensitization, conjunctivitis	NA
Captan		5 mg/m³	NE	NA	Rashes, genetic damage	NA
Carbaryl (Sevin)		5 mg/m³	100 mg/m³	Dust	Small pupils, nasal discharge, sweating, blurred vision	Dust
Carbofuran		100 µg/m³	NE	Dust	Small pupils, nasal discharge, sweating, blurred vision	Dust
Carbon black		3.5 mg/m³	1,750 mg/m³	Dust	None expected	Dust
Carbon dioxide		5,000 ppm	40,000 ppm	no odor	Headache, dizziness, elevated pulse pressure	13.8

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Carbon disulfide (skin)		4 ppm	500 ppm	0.21 ppm	Nervousness, anorexia, psychosis fatigue, sleep disturbance	10.1
Carbon monoxide		25 ppm	1,200 ppm	no odor	Headache, nausea, cyanosis fast breath, chest pain	14.0
Carbon tetrabromide		0.1 ppm	NE	NA	Tears, lung irritation & damage	>11.5
Carbon tetrachloride (skin)		5 ppm	200 ppm	250 ppm	Central nervous system depression, nausea, liver damage	11.5
Carbonyl fluoride		2 ppm	NE	NA	Nose bleeds, stuffy nose nose and throat irritation	NA
Catechol (skin)		5 ppm	NE	NA	Eye, nose & throat irritation convulsions, incoordination	NA
Cellulose		5 mg/m³	NE	Dust	"Dusty lung", spitting	Dust
Cement dust		5 mg/m³	NE	Dust	Coughing, lung irritation	Dust
^{144}Cerium		10 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
^{137}Cesium		60 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
Cesium hydroxide		2 mg/m³	NE	Dust	Extreme corrosion of tissues	Dust
Chlordane (skin)		500 µg/m³	100 mg/m³	no odor	Blurred vision, delirium, twitches, stomach pain, diarrhea	NA
Chlorinated camphene (skin)		500 µg/m³	200 mg/m³	NA	Nausea, confusion, agitation	NA
Chlorinated diphenyl oxide		500 µg/m³	NE	NA	Acne-like dermatitis, liver damage	NA
Chlorine		0.5 ppm	10 ppm	0.08 ppm	Burning eyes, tears, choking	11.5

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Chlorine dioxide		0.1 ppm	5 ppm	5.0 ppm	Irritated eyes, coughing, pulmonary edema, wheezing	10.4
Chlorine trifluoride		C-0.1 ppm	20 ppm	NA	Burning eyes, tearing, corneal ulcers	13.0
Chloroacetaldehyde		C-1 ppm	45 ppm	<1 ppm	Irritated skin, eyes, skin burns	10.6
Chloroacetone (skin)		C-1 ppm	NE	<1 ppm	Irritated skin, eyes, skin burns	<11.0
Chloroacetophenone		0.05 ppm	15 mg/m^3	0.016 ppm	Irritated eyes, nose & throat	9.4
Chloroacetyl chloride (skin)		0.05 ppm	NE	NA	Coughing, rash, dyspnea eye, nose & throat irritation	NA
Chlorobenzene		10 ppm	1,000 ppm	1.3 ppm	Skin & eye irritation incoordination, drowsiness	9.1
Chlorobenzylidene malononitrile (skin)		C-0.05 ppm	2 mg/m^3	0.2 ppm	Burning eyes, crying, coughing conjunctivitis	NA
Chlorobromomethane		200 ppm	2,000 ppm	400 ppm	Disorientation, dizziness, irritated eyes, nose & throat	10.8
Chlorodifluoro methane (Freon 22)		1,000 ppm	NE	NA	Respiratory depression, bronchitis	12.5
Chloroform		2 ppm	500 ppm	192 ppm	Mental dullness, headaches, anesthesia, dizziness	11.4
bis (Chloromethyl) ether		0.001 ppm	Carc.	NA	Pulmonary congestion, coughing irritated eyes, nose & throat	NA
Chloromethyl methyl ether		0.001 ppm	Carc.	NA	Pulmonary congestion, coughing irritated eyes, nose & throat	10.25
1-Chloro-1-nitropropane		2 ppm	100 ppm	NA	Irritated eyes & lungs, blood vessel damage	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Chloropentafluoro-ethane (Freon 115)		1,000 ppm	NE	NA	Bronchial construction, decreased compliance, cardiotoxicity	NA
Chloropicrin		0.1 ppm	2 ppm	1.1 ppm	Eye irritation, tears, coughing, vomiting	NA
Chloroprene (skin)		10 ppm	300 ppm	0.4 ppm	Nervousness, irritability	8.8
Chloropropionic acid (skin)		0.1 ppm	NE	NE	Irritated eyes, nose & throat	NE
Chlorostyrene		50 ppm	NE	NA	No effect known	8.80
Chlorotoluene		50 ppm	NE	NA	Incoordination, dyspnea, red tears	8.83
Chloro (trichloro-methyl) pyridine		.2 mg/m³	NE	NA	NA	NA
Chlorpyrifos (skin)		200 µg/m³	NE	NA	Small pupils, runny nose, headache salivation	NA
Chromic acid & chromates (skin) (insoluble)		50 µg/m³ 10 µg/m³	15 mg/m³	Dust	Respiratory irritation, skin and nasal ulcers	Dust
Chromium compounds		500 µg/m³	250 mg/m³	Dust	Lung damage, skin sensitization	Dust
Chromyl Chloride & chromates (skin)		0.025 ppm	NE	NE	Respiratory irritation, skin and nasal ulcers	NE
Chrysene		200 µg/m³	80 mg/m³	Dust	Eye irritation, dermatitis bronchitis	7.75
Clopidol		5 mg/m³	NE	NA	No effect known	NA
Coal dust (< 5% SiO_2)		2 mg/m³	NE	Dust	Pulmonary fibrosis, spitting	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Cobalt (metal) (dust & fumes)		20 µg/m³	20 mg/m³	>1 mg/m³	Coughing, respiratory sensitivity pneumoconiosis, dyspnea	Dust
Cobalt carbonyl		100 µg/m³	NE	NA	Headache, nausea, pneumonia	NA
Cobalt hydro-carbonyl		100 µg/m³	NE	NA	Headache, nausea, pneumonia	NA
Copper (dust)		1 mg/m³	NE	Dust	Nasal perforation, metal taste	Dust
Copper (fume)		100 µg/m³	NE	Dust	Nasal perforation, metal taste	Dust
Cotton dust		200 µg/m³	500 mg/m³	Dust	Tight chest, coughing, wheezing	Dust
Crag herbicide		5 mg/m³	5,000 mg/m³	Dust	None known in humans	Dust
Cresol (skin)		5 ppm	250 ppm	0.001 ppm	Depression, dyspnea, weak pulse skin & eye burning	9.0
Crotonaldehyde		2 ppm	400 ppm	0.11 ppm	Irritated eyes, dyspnea	9.7
Crufomate		5 mg/m³	NE	NA	Small pupils, runny nose, headache, excitation, salivation	NA
Cumene (skin)		50 ppm	8,000 ppm	0.03 ppm	Irritated eyes, headache, narcosis	8.8
Cyanamide		2 mg/m³	NE	Dust	Eye, nose & throat irritation, flush & fever with alcohol	Dust
Cyanides (skin)		5 mg/m³	25 mg/m³	Dust	Weakness, headache, nausea gasping breath	Dust
Cyanogen		10 ppm	NE	NA	Weakness, headache, nausea gasping breath	13.6
Cyanogen chloride		C-0.3 ppm	50 mg/m³	1 ppm	Pulmonary edema, coughing	12.5

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Cyclohexane		300 ppm	1,300 ppm	780 ppm	Irritated eyes, drowsiness, narcosis	9.9
Cyclohexanol (skin)		50 ppm	400 ppm	0.16 ppm	Irritated eyes, narcosis	10.0
Cyclohexanone (skin)		25 ppm	700 ppm	3.5 ppm	Irritated eyes, narcosis, headache	9.1
Cyclohexene		300 ppm	2,000 ppm	0.41 ppm	Irritated skin & lungs, drowsiness	9.0
Cyclohexylamine		10 ppm	NE	NA	Severe skin irritation, light headedness, drowsiness, anxiety	7.5
Cyclonite (skin)		1.5 mg/m^3	NE	NA	Headache, dizziness, nausea, convulsions	NA
Cyclopentadiene		75 ppm	750 ppm	250 ppm	Irritated eyes, nose	8.58
Cyclopentane		600 ppm	NE	NA	CNS depressant, loss of reflexes	10.52
Cyhexatin		.1 mg/m^3	NE	Dust	Headache, vomiting, psychic disturbance, photophobia	Dust
2,4-D		10 mg/m^3	100 mg/m^3	Dust	Weakness stupor, muscle twitching	Dust
DDT (skin)		1 mg/m^3	500 mg/m^3	2.9 mg/m^3	Numb face, lips & tongue, tremors apprehension, headache	NA
Decaborane (skin)		0.05 ppm	15 mg/m^3	0.35 ppm	Headache, nausea, drowsiness, local muscle spasms	9.9
Demeton (Systox) (skin)		10 $\mu g/m^3$	10 mg/m^3	NA	Aching eyes, headache, & chest small pupils, runny nose	NA
Diacetone alcohol		50 ppm	1,800 ppm	0.27 ppm	Irritated eyes, narcosis, corneal damage	NA
Diazinon (skin)		100 $\mu g/m^3$	NE	NA	Weakness, "tight" chest, small pupils slurred speech	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Diazomethane		0.2 ppm	2 ppm	None	Short breath, flush skin, fever	9.0
Diborane		0.1 ppm	15 ppm	4 ppm	"Tight" chest, vertigo, chills lightheadedness, fever	11.4
Dibrom (Naled) (skin)		3 mg/m³	1,800 mg/m³	NA	Small pupils, headache, irritated eyes, tight chest	NA
1,2-Dibromo-3-chloropropane		0.001 ppm	Carc.	NA	Drowsiness, nausea, vomiting pulmonary edema	NA
2-N-Dibutyl-aminoethanol (skin)		0.5 ppm	NE	NA	Local irritant effects (skin, eyes), GI irritant	NA
Dibutyl cresol		10 mg/m³	NE	NA	Internal bleeding	NA
Dibutyl phenyl phosphate (skin)		0.3 ppm	NE	NA	Respiratory irritation, headache	NA
Dibutyl phosphate		1 ppm	30 ppm	no odor	Respiratory irritation, headache	NA
Dibutyl phthalate		5 mg/m³	4,000 mg/m³	NA	Irritated bronchi & stomach light sensitivity	NA
Dichloroacetylene		C-0.1 ppm	NE	NA	Headaches, nausea, neurological, kidney, lower respir injury	NA
Dichlorobenzene (skin)		25 ppm	150 ppm	0.7 ppm	Nose, eye irritation, skin blister, headaches, nausea, jaundice	9.1
Dichlorobenzidine (skin)		NE	Carc	NA	Skin sensitivity, headache, dizziness, frequent urination	NA
Dichlorobutene		0.005 ppm	Carc	NA	Nose, eye, & skin irritation, blisters	NA
Dichlorodifluoromethane		1,000 ppm	15,000 ppm	NA	Tremors, cardiac arrhythmias	11.8

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Dichlorodimethyl hydantoin		200 µg/m³	5 mg/m³	1.14 ppm	Irritated eyes, throat, & lungs	NA
1,1-Dichloroethane		100 ppm	3,000 ppm	120 ppm	Skin irritation, drowsiness	11.1
1,1 Dichloro-ethylene (vinylidene chloride)		1 ppm	>500 ppm	1.1 ppm	No acute effects	<11.0
1,2 Dichloro-ethylene		200 ppm	1,000 ppm	1.1 ppm	Irritated eyes, CNS depression	10.0
Dichloroethyl ether (skin)		c-0.1 ppm	100 ppm	NA	Tears, irritated nose, coughing, nausea	NA
Dichlorofluoro methane		10 ppm	5,000 ppm	almost no odor	Asphyxia, cardiac arrhythmias	12.39
1,1-Dichloro nitroethane		2 ppm	25 ppm	NA	Irritated eyes, skin & lungs	NA
1,3-Dichloro propene (skin)		1 ppm	NE	NA	Necrosis, edema, tears, respiratory tract irritant	9.82
Dichloro propionic acid		1 ppm	NE	428 ppm	Eye, nose & throat irritation, nausea	NA
Dichlorotetra-fluoroethane		1,000 ppm	15,000 ppm	almost no odor	Respiratory irritation	12.2
Dichlorvos (DDVP) (skin)		0.1 ppm	100 mg/m³	NA	Small pupils, aching eyes, headache, runny nose	NA
Dicrotophos (skin)		250 µg/m³	NE	NA	Salivation, sweating, small pupils	NA
Dicyclopentadiene		5 ppm	NE	0.011 ppm	Eye & throat irritation, headache	NA
Dicyclopenta-dienyl iron		5 mg/m³	NE	NA	None known.	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Dieldrin (skin)		0.25 mg/m³	50 mg/m³	0.041 ppm	Headache, dizziness, vomiting nausea, convulsions	NA
Diethanolamine (skin)		0.46 ppm	NE	0.04 ppm	Eye irritation & burning	NA
Diethylamine		5 ppm	200 ppm	0.06 ppm	Eye, skin irritation	8.0
Diethylamino ethanol (skin)		2 ppm	100 ppm	0.01 ppm	Nausea, respiratory irritation	NA
Diethylene triamine (skin)		1 ppm	NE	10 ppm	Skin, eye & nose & throat irritant, skin sensitization	NA
Diethyl ketone		200 ppm	NE	2.8 ppm	Eye, nose & throat irritation drowsiness	9.32
Diethyl phthalate		5 mg/m³	NE	NA	Pain in arms and legs	NA
Difluorodibromo methane		100 ppm	2,000 ppm	inadeq.	Irritated nose, drowsiness	11.1
Diglycidyl ether (DGE)		0.1 ppm	10 ppm	5 ppm	Eye, nose & throat irritation dizziness	NA
Diisobutyl ketone		25 ppm	500 ppm	110 ppb	Irritated eyes & skin, headache, dizziness	9.04
Diisopropylamine (skin)		5 ppm	200 ppm	130 ppb	Nausea, headache, eye irritation, visual disturbances	7.7
Dimethyl acetamide (skin)		10 ppm	300 ppm	46.8 ppm	Jaundice, depression, lethargy, delusions	8.8
Dimethylamine		5 ppm	500 ppm	470 ppb	Irritated eyes, coughing, pulmonary edema	8.2

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Dimethylamino-azobenzene		NE	Carc.	NA	Coughing, difficulty breathing, bloody sputum	NA
Dimethylaniline (skin)		5 ppm	100 ppm	NA	Weakness, dizziness, cyanosis	7.14
Dimethyl ethoxysilane		0.5 ppm	Carc.	NA	Skin, nose & eye irritation	NA
Dimethylformamide (skin)		10 ppm	500 ppm	100 ppm	Colic, high blood pressure, face flush, nausea	9.12
1,1-Dimethyl-hydrazine (skin)		0.5 ppm	15 ppm	9.2 ppm	Irritated eyes, choking, lethargy, chest pain	8.05
Dimethyl phthalate		5 mg/m³	2,000 mg/m³	NA	Irritated nasal passages, eye pain	9.75
Dimethyl sulfate (skin)		0.1 ppm	7 ppm	almost no odor	Irritated eyes, headache, giddiness, difficult speech	NA
Dinitolmide (zoalene)		5 mg/m³	NE	NA	None shown	NA
Dinitrobenzene (skin)		0.15 ppm	50 mg/m³	NA	Cyanosis, bad taste, visual disturbance	10.71
Dinitrocresols (skin)		0.2 mg/m³	5 mg/m³	no odor	Sense of well being, headache, fever, fast pulse	NA
Dinitrotoluene (skin)		150 µg/m³	50 mg/m³	almost no odor	Anoxia, cyanosis, anemia	NA
Dioctyl phthalate		5 mg/m³	5,000 mg/m³	NA	Irritated eyes, nausea, diarrhea	NA
Dioxane (skin)		25 ppm	500 ppm	12 ppm	Eye irritation, headache, nausea, drowsiness	9.13
Dioxins	Contact H&S for limits					

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Dioxathion (skin)		200 µg/m³	NE	NA	Conjunctivitis, excitability	NA
Diphenyl		0.2 ppm	100 mg/m³	NA	Irritated throat, headache, nausea, fatigue, numbness	8.27
Diphenylamine		10 mg/m³	NE	NA	Fast pulse, eczema	7.4
Dipropylene glycol methyl ether (skin)		100 ppm	600ppm	100 ppm	Irritated eyes, lightheadedness, headaches	NA
Dipropyl ketone		50 ppm	NE	NA	Narcosis, eye, nose & throat irritation	NA
Diquat		0.5 mg/m³	NE	NA	Abdominal cramping, nausea vomiting	NA
Disulfiram		2 mg/m³	NE	NA	With alcohol: flushing, nausea, vomiting	NA
Disulfoton (skin)		100 µg/m³	NE	NA	Conjunctivitis, excitability, salivation, small pupils	NA
Diuron		10 mg/m³	NE	NA	None shown	NA
Divinyl benzene		10 ppm	NE	NA	Moderately irritant to eyes & respiratory system	NA
Emery (dust)		5 mg/m³	NE	Dust	Pulmonary fibrosis	Dust
Endosulfan (skin)		100 µg/m³	NE	NA	Headaches, dizziness, nausea, convulsions	NA
Endrin (skin)		100 µg/m³	2 mg/m³	NA	Convulsions, stupor, headache, dizziness	NA
Enflurane		75 ppm	10,000 ppm	slight odor	narcosis, depressed mental function	<11.0

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Epichlorohydrin (skin)		2 ppm	75 ppm	10 ppm	Stomach pains, respiratory distress eye irritation, runny nose	10.64
EPN (skin)		100 µg/m³	5 mg/m³	inadeq.	Small pupils, tight chest, runny nose	NA
Ethanolamine		3 ppm	30 ppm	3 ppm	Irritated skin, eyes, lethargy	8.96
Ethion (skin)		400 µg/m³	NE	Mist	Blurred vision, salivation, nausea excitation, twitching	Mist
2-Ethoxyethanol (skin)		5 ppm	500 ppm	2.7 ppm	Blood damage, irritated eyes & lungs	NA
2-Ethoxyethyl acetate (skin)		5 ppm	500 ppm	0.06 ppm	Irritated eyes, vomiting, paralysis	NA
Ethyl acetate		400 ppm	2,000 ppm	18 ppm	Irritated eyes & nose, narcosis	10.10
Ethyl acrylate (skin)		5 ppm	300 ppm	0.3 ppb	Irritated eyes, respiratory system	10.30
Ethyl alcohol		1,000 ppm	3,300 ppm	180 ppm	Irritation, lightheadedness, headache, incoordination	10.48
Ethylamine (skin)		5 ppm	600 ppm	27 ppm	Irritated eyes, respiratory irritation, skin burns	8.86
Ethyl amyl ketone		25 ppm	3,000 ppm	NA	Irritated eyes, headache, narcosis	9.19
Ethyl benzene		100 ppm	800 ppm	200 ppm	Eye & nose irritation, headache, narcosis	8.76
Ethyl bromide (skin)		5 ppm	2,000 ppm	25 ppm	Irritated eyes, pulmonary edema, liver disease, dizziness	10.29
Ethyl butyl ketone		50 ppm	1,000 ppm	<100 ppm	Irritated eyes & nose, headache, narcosis	9.15

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Ethyl chloride		1,000 ppm	3,800 ppm	NA	Incoordination, stomach cramps Cardiac arrhythmia	10.97
Ethylene chlorohydrin (skin)		C-1 ppm	7 ppm	no odor	Vomiting, vertigo, headache low blood pressure	10.90
Ethylenediamine		10 ppm	1,000 ppm	3.4 ppm	Irritated respiratory system, asthma, skin sensitization	8.6
Ethylene dibromide (skin)		20 ppm	100 ppm	25 ppm	Eye, nose & throat irritation, hives	9.45
Ethylene dichloride		1 ppm	50 ppm	26 ppm	Nervous system depression, irritated eyes, corneal opacity	11.05
Ethylene glycol		C-50 ppm	NE	0.64 ppm	Central nervous system depression, drunkenness, nausea, vomiting	NA
Ethylene glycol dinitrate (skin)		0.05 ppm	75 ppm	NA	Throbbing headache, nausea, flushing, stomach pain	NA
Ethyleneimine (skin)		0.5 ppm	100 ppm	NA	Nausea, headache, skin sensitivity burning eyes	9.2
Ethylene oxide		1 ppm	800 ppm	420 ppm	Peculiar taste, headache, nausea dyspnea	10.56
Ethyl ether		400 ppm	1,900 ppm	0.83 ppm	Drowsiness, headaches, excitation dizziness, eye, nose & throat irritation	9.53
Ethyl formate		100 ppm	1,500 ppm	NA	Irritated eyes & lungs, narcosis	10.61
Ethylidene norbornene		C-5 ppm	NE	0.073 ppm	None known	NA
Ethyl mercaptan		0.5 ppm	500 ppm	0.4 ppb	Headache, nausea, incoordination	9.29
N-Ethylmorpholine (skin)		5 ppm	100 ppm	0.1 ppm	Eye & nose irritation, visual distress	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Ethyl silicate		10 ppm	700 ppm	3.6 ppm	Irritated eyes, nose, weeping dyspnea	9.77
Fenamiphos (skin)		100 µg/m³	NE	NA	Excitation, salivation, nausea twitches, blurry vision	NA
Fensulfothion		100 µg/m³	NE	NA	Excitation, salivation, nausea twitches, blurry vision	NA
Fenthion (skin)		200 µg/m³	NE	NA	Excitation, salivation, nausea twitches, blurry vision	NA
Ferbam (dust)		10 mg/m³	800 mg/m³	Dust	Irritated eyes, respiratory tract, GI distress	7.72
Ferrovanadium (dust)		1 mg/m³	500 mg/m³	Dust	Irritated eyes, bronchitis	Dust
Fibrous glass		5 mg/m³	NE	Dust	Nose & throat irritation, coughing	Dust
Fluorides		2.5 mg/m³	250 mg/m³	Dust	Irritated eyes, stomach pain, diarrhea, excess salivation	Dust
Fluorine		0.1 ppm	25 ppm	100 ppm	Eye, nose & throat irritation laryngeal spasms, skin burns	15.7
Fonofos (skin)		100 µg/m³	NE	NA	None shown	NA
Formaldehyde		0.3 ppm	20 ppm	1 ppm	Irritated eyes, weeping, vomiting, bronchial spasms	10.88
Formamide (skin)		10 ppm	NE	100 ppm	Weight loss, birth defects	10.20
Formic acid (skin)		5 ppm	30 ppm	239 ppm	Irritated eyes, nasal discharge, nausea	11.05
Furfural (skin)		2 ppm	100 ppm	50 ppm	Irritated eyes, headache	9.21
Furfuryl alcohol (skin)		10 ppm	75 ppm	8 ppm	Dizziness, nausea, respiratory depression, hypothermia	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Gasoline		300 ppm	NE	10 ppm	Vomiting, diarrhea, insomnia, dizziness, headache	NA
Germanium tetrahydride		0.2 ppm	≤50 ppm	NA	Weakness, headache, stomach pain, nausea	NA
Glutaraldehyde		C-0.2 ppm	NE	NA	Eye, nose & throat irritation skin sensitization	NA
Glycerin (mist)		5 mg/m³	NE	NA	None shown	NA
Glycidol		25 ppm	150 ppm	NA	Irritated eyes & skin, narcosis	NA
Grain dust		4 mg/m³	NE	Dust	Coughing, wheezing, short breath	Dust
Graphite dust		2 mg/m³	NE	Dust	Coughing, short breath, black sputum	Dust
Gypsum		5 mg/m³	NE	Dust	"Dusty lung", spitting, coughing	Dust
Hafnium		500 µg/m³	50 mg/m³	NA	Irritated eyes & skin	NA
Halothane		50 ppm	10,000 ppm	slight odor	Narcosis, cardiac arrhythmia,	NE
Heptachlor & epoxides (skin)		50 µg/m³	35 mg/m³	0.02 ppm	Tremors, convulsions	NA
Heptane		400 ppm	750 ppm	220 ppm	Giddiness, no appetite, pneumonia	9.9
Hexachloro-benzene (skin)		0.025 mg/m³	NE	Dust	Restlessness, anorexia, lung irritation, photosensitivity	Dust
Hexachloro-butadiene (skin)		0.02 ppm	Carc.	NA	Eye, nose & throat irritation Kidney damage	NA
Hexachloro-cyclopentadiene		0.01 ppm	NE	0.33 ppm	Skin & mucous membrane irritation, headaches	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Hexachloroethane (skin)		1 ppm	300 ppm	NA	Irritated eyes, cancer	11.22
Hexachloro-naphthalene (skin)		200 µg/m³	2 mg/m³	NA	Acne, confusion, jaundice	NA
Hexafluoroacetone (skin)		0.1 ppm	NE	NA	Anemia, testicular degeneration	11.81
Hexamethylene diisocyanate		0.005 ppm	10 ppm	NE	Respiratory distress, weakness	NE
Hexamethyl phosphoramide (skin)		NE	>4 ppm	NE	Runny nose, cancer	NE
n-Hexane		50 ppm	1,100 ppm	1,500 ppm	Nausea, headache, giddiness, wrist & foot drop, numb feet & hands	10.17
Hexane (other isomers)		500 ppm	5,000 ppm	1,500 ppm	Nausea, vertigo, anesthetic, euphoria	10.17
Hexane diamine		0.5 ppm	NE	NE	Irritated eyes, nose & throat,	NE
2-Hexanone (MBK - skin)		5 ppm	1,600 ppm	NA	Wrist & foot drop, headache, drowsiness, numb feet & hands	9.34
Hexyl acetate		50 ppm	500 ppm	100 ppm	Irritated eyes, nose & throat, narcosis, headache	NA
Hexylene glycol		C-25 ppm	NE	NA	Irritated eyes, narcosis	NA
Hydrazine (skin)		0.1 ppm	50 ppm	4 ppm	Irritated eyes, temporary blindness, nausea, dizziness	8.10
Hydrogenated terphenyls		0.5 ppm	NE	NA	Reversible skin rash, headache	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Hydrogen bromide		C-3 ppm	30 ppm	6 ppm	Irritated eyes, nose & throat, skin burns	11.62
Hydrogen chloride		C-5 ppm	50 ppm	10 ppm	Burns throat & eyes, choking	12.74
Hydrogen cyanide (skin)		4.7 ppm	50 ppm	1 ppm	Weakness, headaches, nausea, confusion, fast, deep breathing	13.73
Hydrogen fluoride		C-3 ppm	30 ppm	5 ppm	Irritated eyes, nose & throat, pulmonary edema, stuffy nose	15.77
Hydrogen peroxide		1 ppm	75 ppm	100 ppm	Irritated eyes, nose & throat, corneal ulcer	10.54
Hydrogen selenide		0.05 ppm	1 ppm	1.5 ppm	Nausea, diarrhea, metal taste, garlic breath, Irritated eyes & nose	9.88
Hydrogen sulfide		10 ppm	100 ppm	9.4 ppb	Conjunctivitis, headache, fatigue photophobia, crying, dizziness	10.46
Hydroquinone		2 mg/m³	50 mg/m³	NA	Irritated eyes, excitement, nausea colored urine, dizziness	7.95
Hydroxypropyl acrylate (skin)		0.5 ppm	NE	NA	Irritated eyes, skins sensitization	NA
Indene		10 ppm	NE	NA	Irritated eyes, nose & throat, liver damage	8.81
Indium		100 µg/m³	NE	NA	Short breath, pneumonia	NA
Iodine		C-0.1 ppm	2 ppm	1.6 ppm	Irritated eyes, tight chest, weeping, skin sensitization	9.28
Iodoform		0.6 ppm	NE	5 ppb	Irritated eyes, tight chest, weeping, skin sensitization	NA
Iron oxide (dust)		5 mg/m³	2,500 mg/m³	Dust	Benign pneumoconiosis, cough	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Iron penta-carbonyl		0.1 ppm	NE	NA	Headache, dizziness, fever, coughing, short breath	7.95
Iron salts (soluble)		1 mg/m³	NE	NA	Skin & stomach irritation	NA
Isoamyl acetate		100 ppm	1,000 ppm	0.22 ppm	Irritated eyes, nose, & throat, narcosis	9.95
Isoamyl alcohol		100 ppm	500 ppm	1 ppm	Irritated eyes, headache, dizziness, diarrhea	10.09
Isobutyl acetate		150 ppm	1,300 ppm	1.1 ppm	Headache, drowsiness, irritated eyes & lungs	9.97
Isobutyl alcohol		50 ppm	1,600 ppm	3.6 ppm	Irritated eyes, headache, drowsiness	10.09
Isooctyl alcohol (skin)		50 ppm	NE	17 ppm	Skin irritation, incoordination	NA
Isophorone		4 ppm	200 ppm	0.19 ppm	Irritated eyes, nose & throat, headache, narcosis,	9.07
Isophorone diisocyanate (skin)		0.005 ppm	NE	NA	"Asthma," loss of breath	NA
2-Isopropoxy-ethanol (skin)		25 ppm	NE	NA	Brown urine, lung congestion, anemia	NA
Isopropyl acetate		250 ppm	1,800 ppm	4.1 ppm	Irritated eyes, narcosis, headache	9.98
Isopropyl alcohol		400 ppm	2,000 ppm	43 ppm	Mild irritated eyes, drowsiness, gastrointestinal cramps	10.15
Isopropyl amine		5 ppm	750 ppm	0.2 ppm	Irritated eyes, pulmonary edema, visual disturbance	8.72

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Isopropyl aniline (skin)		2 ppm	NE	NA	Eye, nose, throat & skin irritation brown urine	7.50
Isopropyl ether		250 ppm	1,400 ppm	0.05 ppm	Irritated eyes, respiratory discomfort	9.20
Isopropyl glycidyl ether (IGE)		50 ppm	400 ppm	300 ppm	Irritated eyes, upper respiratory	NA
Kaolin		2 mg/m³	NE	Dust	"Dusty lung", spitting, coughing	Dust
Ketene		0.5 ppm	5 ppm	23 ppm	Irritated eyes & lungs, pulmonary edema, skin sensitization	9.61
Lead compounds		50 µg/m³	100 mg/m³	Dust	Fatigue, pallor, colic, insomnia	Dust
^{212}Lead		10 pCi/l	NE	Dust	Carcinogen. No warning property	Dust
Limestone dust		5 mg/m³	NE	Dust	Irritated eyes & respiratory tract	Dust
Lindane (skin)		500 µg/m³	50 mg/m³	21 mg/m³	Headache, nausea, clonic convulsions, difficult breathing	NA
Lithium hydride		25 µg/m³	0.5 mg/m³	100 µg/m³	Irritated eyes, nausea, confusion, muscle twitches	NA
Magnesite (dust)		5 mg/m³	NE	Dust	"Dusty lung", spitting, chest pain	Dust
Magnesium oxide		10 mg/m³	750 mg/m³	Dust	Flu-like fever, cough	Dust
Malathion (dust) (skin)		10 mg/m³	250 mg/m³	10 mg/m³	Small pupils, runny nose, headache tight chest, incoordination	Dust
Maleic anhydride		0.25 ppm	10 mg/m³	0.5 ppm	Double vision, asthma, photophobia	9.9
Manganese (dust)		5 mg/m³	500 mg/m³	Dust	"Dead face", dry throat, cough	Dust
(fume)		1 mg/m³		Dust	metal fume fever, pneumonia	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Manganese cyclopentadienyl tricarbonyl (skin)		100 µg/m³	NE	NA	Skin irritation	NA
Marble		5 mg/m³	NE	Dust	"Dusty lung", spitting, coughing	Dust
Mercury and compounds (skin)		50 µg/m³	10 mg/m³	NA	Severe abdominal pain tremors, weakness, GI irritation, fatigue	10.4
Mercury - alkyl compounds (skin)		10 µg/m³	2 mg/m³	NA	Twitches, dizziness, numbness hypersalivation	9.0
Mesityl oxide (skin)		15 ppm	1,400 ppm	17 ppb	Irritated eyes, nose & throat, narcosis	9.08
Methacrylic acid (skin)		20 ppm	NE	NA	Irritated eyes, nose & throat	NA
Methane		3,000	6,250 ppm	No odor	No toxicity, explosive	12.8
Methanol (skin)		200 ppm	6,000 ppm	160 ppm	Drowsiness, loss of vision, unconsciousness	10.85
Methomyl		2.5 mg/m³	NE	NA	NA	NA
Methoxychlor		10 mg/m³	5,000 mg/m³	NA	Twitches, convulsions	NA
Methoxyethanol (skin)		5 ppm	200 ppm	2.4 ppm	Headache, drowsiness, tremors weakness	9.6
Methoxyethyl acetate (skin)		5 ppm	200 ppm	0.34 ppm	Brain damage, eye irritation, narcosis	NA
4-Methoxyphenol		5 mg/m³	NE	<1 ppm	Irritated eyes, nose & throat, skin necrosis	NA
Methyl acetate		200 ppm	3,100 ppm	180 ppm	Irritated nose & throat, headache, drowsiness	10.27

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Methyl acetylene		1,000 ppm	1,700 ppm	100 ppm	Excitability, tremors, numbness	10.36
MAPP mixture		1,000 ppm	3,400 ppm	100 ppm	Excitability, tremors, numbness	10.36
Methyl acrylate (skin)		10 ppm	250 ppm	75 ppm	Irritated eyes, lungs & skin	9.90
Methyl acrylonitrile (skin)		1 ppm	NE	7 ppm	Vomiting, convulsions, chemical asphyxia	NA
Methylal		1,000 ppm	2,200 ppm	NA	Mild irritation of eyes & throat, anesthesia	10.00
Methylamine		5 ppm	100 ppm	5 ppm	Irritated eyes, coughing, burning throat	8.97
Methyl amyl ketone		25 ppm	800 ppm	0.01 ppm	Irritated eyes, nose & throat, headache, narcosis	9.33
Methyl aniline (skin)		0.5 ppm	50 ppm	NA	Dizziness, headache, dyspnea	7.34
Methyl bromide (skin)		5 ppm	250 ppm	>20 ppm	Headache, visual disturbances, vertigo, tremors	10.53
Methyl t-butyl ether		40 ppm	NA	≤0.5 ppm	Drowsiness, eye irritation, incoordination, rapid breathing	<9.40
Methyl butyl ketone (see Hexanone)						
Methyl chloride		50 ppm	2,000 ppm	10 ppm	Nausea, stagger, slurred speech, disturbed vision	11.28
Methyl 2-cyanoacrylate		2 ppm	3 ppm	NA	"Superglue" adhesion	NA
Methyl cyclohexane		400 ppm	1,200 ppm	500 ppm	Lightheadedness, drowsiness, nose & throat irritation	9.85

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Methyl cyclohexanol		50 ppm	500 ppm	500 ppm	Headache, irritated eyes	9.80
Methyl cyclo-hexanone (skin)		50 ppm	600 ppm	NA	Eye, nose & throat irritation, narcosis	NA
Methyl cyclopenta-dienyl manganese tricarbonyl (skin)		200 µg/m³	NE	NA	"Thick tongue" giddiness, nausea headache	NA
Methyl demeton (skin)		500 µg/m³	NE	<1 mg/m³	Nausea, headache, dizziness vomiting, "red nose"	NA
Methylene bis chloroaniline (skin)		0.01 ppm	100 ppm	NA	Brown urine, nausea, liver cancer	NA
Methylene bis cyclohexyl isocyanate (skin)		0.005 ppm	NE	NA	Chest pain, tremors	NA
Methylene bisphenyl isocyanate		0.005 ppm	75 mg/m³	NA	Chest pain, dyspnea, "asthma"	NA
Methylene chloride		50 ppm	2,300 ppm	160 ppm	Weakness, tingling & numbness, vertigo, nausea	11.35
Methylene dianiline (skin)		0.01 ppm	4 ppm	0.5 ppm	eye, nose & throat irritation, fever, yellow skin, brown urine	NE
Methyl ethyl ketone (MEK)		200 ppm	3,000 ppm	5.5 ppm	Irritated eyes, dizziness, vomiting	9.53
Methyl ethyl ketone peroxide		C-0.2 ppm	NE	NA	Eye, nose & throat irritation, lung damage	NA
Methyl formate		100 ppm	4,500 ppm	2,000 ppm	Eye & nose irritation, chest oppression	10.81
Methyl hydrazine (skin)		C-0.2 ppm	20 ppm	3 ppm	Tremors, vomiting, incoordination, diarrhea	7.67

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Methyl iodide (skin)		2 ppm	100 ppm	4,300 ppm	Nausea, vertigo, slurred speech	9.54
Methyl isoamyl ketone		50 ppm	NE	0.013 ppm	Eye, nose & throat irritation, narcosis	NA
Methyl isobutyl carbinol (skin)		25 ppm	400 ppm	NA	Eye irritation, headache, drowsiness	NA
Methyl isobutyl ketone (Hexone)		50 ppm	500 ppm	0.88 ppm	Irritated eyes, nose & throat, narcosis, headache	9.30
Methyl isocyanate (skin)		0.02 ppm	3 ppm	2 ppm	Chest pain, dyspnea, asthma eye, nose, & throat irritation	10.67
Methyl isopropyl ketone		200 ppm	NE	NA	Narcosis, nausea, dizziness, incoordination	NA
Methyl mercaptan		0.5 ppm	150 ppm	1 ppb	Narcosis, cyanosis, headache, nausea, convulsions	9.44
Methyl methacrylate		100 ppm	1,000 ppm	49 ppb	Irritated eyes, nose & throat, narcosis	9.70
Methyl parathion (skin)		200 μg/m³	NE	NA	Sweating, salivation, fast pulse, twitches, diarrhea	NA
Methyl pyrolidone		100 ppm	>400 ppm	<400 ppm	Headache, giddiness, nausea, confusion	NE
Methyl silicate		1 ppm	NE	NA	Early ulceration of cornea	NA
Methyl styrene		50 ppm	700 ppm	0.16 ppm	Irritated eyes, nose & throat, drowsiness	8.35
Metribuzin		5 mg/m³	NE	Dust	None known	Dust
Mica (dust)		3 mg/m³	1,500 mg/m³	Dust	Cough, dyspnea, weakness, weight loss	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Molybdenum compounds		5 mg/m³	1,000 mg/m³	Dust	Loss of appetite, incoordination, eye, nose & throat irritation	Dust
Monocrotophos (skin)		0.25 mg/m³	NE	Dust	small pupils, salivation, fast pulse, twitches, eye irritation	NA
Morpholine (skin)		20 ppm	1,400 ppm	0.11 ppm	Visual disturbance, cough, eye, nose & throat irritation	8.88
Naphtha (coal tar)		100 ppm	1,000 ppm	300 ppm	Lightheadedness, drowsiness	NA
Naphthalene		10 ppm	250 ppm	38 ppb	Eye irritation, headache, confusion, excitement, nausea	8.12
Naphthylamine (α & β)		NE	Carc.	NA	Short breath, blood in urine, difficult urination	7.30
Nickel (dust)		1 mg/m³	10 mg/m³	Dust	Skin sensitivity, chest pain	Dust
(soluble compounds)		100 µg/m³		Dust	"asthma"	Dust
Nickel carbonyl		0.001 ppm	2 ppm	3 ppm	Headache, vertigo, nausea, epigastric pain, pneumonia	8.28
Nicotine (skin)		500 µg/m³	5 mg/m³	NA	Nausea, salivation, stomach pain, diarrhea, headache	8.01
^{95}Niobium		500 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
Nitrapyrin		5 mg/m³	NE	Dust	NE	Dust
Nitric acid		2 ppm	25 ppm	62 ppm	Irritated eyes, nose & throat, delayed pulmonary edema	11.95
Nitric oxide		25 ppm	100 ppm	1 ppm	Irritated eyes, nose & throat, drowsiness	9.25
Nitroaniline (skin)		3 mg/m³	300 mg/m³	no odor	Cyanosis, dyspnea, diarrhea, irritability, vomiting	8.85

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Nitrobenzene (skin)		1 ppm	200 ppm	0.037 ppm	Irritated eyes, nausea, dyspnea	9.92
4-Nitrobiphenyl		NE	Carc.	NA	Headache, dyspnea, weakness, urinary burning	NA
Nitrochloro-benzene (skin)		0.1 mg/m³	100 mg/m³	0.002 ppm	Unpleasant taste, dizziness, weakness, nausea	9.99
Nitroethane		100 ppm	1,000 ppm	500 ppm	Dermatitis, crying, short breath	10.88
Nitrogen dioxide		1 ppm	50 ppm	20 ppm	Frothy sputum, dyspnea, cyanosis	9.78
Nitrogen trifluoride		10 ppm	1,000 ppm	No odor	Weakness, dizziness, headache	12.97
Nitroglycerin (skin)		C-100 µg/m³	75 mg/m³	NA	Throbbing headache, nausea, dizziness	NA
Nitromethane		20 ppm	750 ppm	500 ppm	Dermatitis	11.08
1-Nitropropane		25 ppm	1,000 ppm	140 ppm	Eye irritation, vomit, diarrhea	10.81
2-Nitropropane		10 ppm	100 ppm	300 ppm	Headache, anorexia, irritated respiratory system	10.71
Nitroso-dimethylamine (skin)		NE	Carc.	NA	Diarrhea, stomach cramps, headache, fever	8.69
Nitrotoluene (skin)		2 ppm	200 ppm	1.7 ppm	Cyanosis, headache, dizziness	9.82
Nitrous oxide		50 ppm	>1,000 ppm	none	Cough, fatigue, and nausea	NE
Nonane		200 ppm	NE	NA	Mild tremors, slight incoordination	10.21
Octachloro naphthalene (skin)		100 µg/m³	≤200 mg/m³	NA	Acne-like dermatitis, jaundice	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Octane		300 ppm	1,000 ppm	150 ppm	Irritated eyes, nose & throat, pneumonia, drowsiness	9.82
Oil mist		5 mg/m³	2,500 mg/m³	Mist	Nasal irritation	Mist
Osmium tetroxide		1.6 µg/m³	1 mg/m³	0.002 ppm	Tears, conjunctivitis, headache, cough	12.6
Oxalic acid		1 mg/m³	500 mg/m³	NA	Irritated lungs, shock, headache	NA
Oxygen difluoride		C-0.05 ppm	0.5 ppm	0.45 ppm	Intractable headache, respiratory irritation	13.11
Ozone		0.1 ppm	5 ppm	20 ppb	Irritated eyes, nose & throat, pulmonary edema	12.50
Paraffin wax fume		2 mg/m³	NE	NA	Eye, nose & throat irritation	NA
Paraquat dust (skin)		100 µg/m³	1.0 mg/m³	Dust	Irritated eyes, fingernail damage, pulmonary inflammation, nosebleeds	Dust
Parathion (skin)		100 µg/m³	10 mg/m³	480 µg/m³	Small pupils, runny nose, headache, salivation, stomach cramps	NA
Particulates (N.O.S.)						
- Total dust		10 mg/m³	NE	Dust	Respiratory irritation, eye irritation, spitting	Dust
- Respirable		5 mg/m³	NE	Dust		Dust
Pentaborane		0.005 ppm	1 ppm	1 ppm	Headache, drowsiness, dizziness tremor, incoordination	9.90
Pentachloro napthalene (skin)		500 µg/m³	NE	NA	Headache, vertigo, "acne" itching, fatigue	NA
Pentachlorophenol (skin)		500 µg/m³	2.5 mg/m³	9.3 mg/m³	Irritated eyes, & nose, lost appetite weakness, sweating, sneezing	NA
Pentaerythritol		5 mg/m³	NE	Dust	"Dusty lung", spitting	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Pentane		600 ppm	1,500 ppm	10 ppm	Eye, nose & throat irritation, drowsiness, pneumonia, headache	10.34
2-Pentanone		200 ppm	1,500 ppm	8 ppm	Irritated eyes, headache, narcosis	9.39
Perchloromethyl mercaptan		0.1 ppm	10 ppm	<0.1 ppm	Crying, eye inflammation, coughing, dyspnea, vomiting	NA
Perchloryl fluoride		3 ppm	100 ppm	10 ppm	Lung irritation, skin burns, weakness, dizziness, headache	13.6
Perlite		5 mg/m^3	NE	Dust	"Dusty lung", spitting, coughing	Dust
Petroleum distillates (Naphtha)		300 ppm	1,100 ppm	NA	Dizziness, drowsiness, headache, irritated eyes, nose & throat	NA
Phenol (skin)		5 ppm	250 ppm	0.06 ppm	Skin corrosive, eye irritant, muscle aches, dark urine	8.5
Phenothiazine (skin)		5 mg/m^3	NE	NA	Itching, photosensitivity, anemia	NA
Phenylene diamine (skin)		100 $\mu g/m^3$	$\leq$25 mg/m^3	NA	Irritated throat, "asthma"	7.58
(di)Phenyl ether		1 ppm	100 ppm	0.1 ppm	Nausea, irritated eyes, nose	8.09
Phenyl glycidyl ether		0.1 ppm	100 ppm	NA	Skin sensitivity, irritated eyes, nose, & throat, narcosis	NA
Phenylhydrazine (skin)		0.1 ppm	15 ppm	NA	Skin sensitization, dyspnea, cyanosis	7.64
Phenyl mercaptan		0.5 ppm	NE	0.3 ppb	Restlessness, fast breathing, weakness, incoordination, paralysis	8.32
N-Phenyl β-naphtylamine		NE	Carc.	None	Carcinogen. No warning property	NE

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Phenylphosphine		C-0.05 ppm	NE	NA	Lost appetite, nausea, diarrhea, tears, tremors	7.36
Phorate (skin)		50 µg/m³	NE	NA	Small pupils, headache, salivation, diarrhea, stomach cramps	NA
Phosdrin (skin)		0.01 ppm	4 ppm	NA	Small pupils, headache, salivation, diarrhea, stomach cramps	NA
Phosgene		0.1 ppm	2 ppm	1.0 ppm	Dry burning throat, vomiting, foamy sputum, short breath	11.55
Phosphine		0.3 ppm	50 ppm	0.14 ppm	Nausea, diarrhea, thirst, chills	10.0
Phosphoric acid		1 mg/m³	1000 mg/m³	NA	Irritated upper respiratory tract, burns skin & eyes	NA
Phosphorus (yellow)		100 µg/m³	5 mg/m³	NA	Irritated eyes, stomach pain, excess salivation, jaw pain	11.1
Phosphorous oxychloride		0.1 ppm	NE	NA	Eye irritation, dizziness, nausea headache, chest pain	NA
Phosphorus pentachloride		0.85 mg/m³	70 mg/m³	NA	Irritated eyes, respiratory system, bronchitis	NA
Phosphorus pentasulfide		1 mg/m³	250 mg/m³	0.005 ppm	Photophobia, dizziness, headache tears, conjunctivitis	NA
Phosphorus trichloride		0.2 ppm	25 ppm	4 ppm	Irritated eyes, nose, pulmonary edema	9.91
Phthalic anhydride		6 mg/m³	60 mg/m³	0.12 ppm	Nausea, nasal ulcer & bleeding, bronchitis	10.0
Phthalodinitrile		5 mg/m³	NE	NA	Weight loss	NA
Picloram		5 mg/m³	NE	NA	Dermatitis, diarrhea, fast pulse, vaginal bleeding	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Picric acid (skin)		100 $\mu g/m^3$	75 mg/m^3	0.4 $\mu g/m^3$	Weakness, bitter taste, blood in urine, difficult urination	NA
Pindone (Pival)		100 $\mu g/m^3$	100 mg/m^3	NA	Nosebleed, stomach & back pain, smokey urine, profuse bleeding	NA
Piperazine dihydrochloride		5 mg/m^3	NE	NA	Eye, nose & throat irritation, skin burns, sensitization	NA
Plaster (dust)		5 mg/m^3	NE	Dust	"Dusty lung", spitting, coughing	Dust
Platinum						
- Metal		1 mg/m^3	4 mg/m^3	Dust	Cough, dyspnea, cyanosis, skin sensitization	Dust
- Soluble salts		2 $\mu g/m^3$				
^{239}Plutonium		0.003 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
Polychlorinated biphenyl (PCBs - skin)		500 $\mu g/m^3$	5 mg/m^3	Mist	Irritated eyes, chloracne	Mist
Polychlorinated dibenzodioxins		1 $\mu g/m^3$ (hex isomers,	Carc. Company-internal)	Dust	Chloracne, loss of feeling fatigue	Dust
Polychlorinated dibenzofurans		1 $\mu g/m^3$ (hex isomers,	Carc. Company-internal)	Dust	Chloracne, loss of feeling fatigue	Dust
Polynuclear aromatics		200 $\mu g/m^3$	80 mg/m^3	Dust	Confusion, nausea, eye irritant headaches, stomach pain	Dust
Portland cement		5 mg/m^3	5,000 mg/m^3	Dust	Coughing, spitting, wheezing lung irritation sneezing	Dust
Potassium hydroxide		C-2 mg/m^3	NE	Dust	Eye, nose & throat irritation, nasal ulcers, lung damage	Dust
^{144}Praseodymium		50,000 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
^{147}Promethium		50 pCi/l	NE	Dust	Carcinogen - no warning property	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Propane		1,000 ppm	2,100 ppm	>20,000 ppm	Dizziness, disorientation, excitation	11.00
Propane sultone		NE	NE	<10 ppm	Carcinogen. No warning property.	NE
Propanoic acid		10 ppm	NE	66 ppb	Eye, nose & throat irritation, skin burns, coughing, "asthma"	10.24
Propargyl alcohol (skin)		1 ppm	NE	NA	Eye, nose & throat irritation, tears	10.51
Propriolactone		0.5 ppm	Carc.	NA	Skin irritation, burns, frequent urination	9.7
Propoxur (Baygon)		500 µg/m³	NE	NA	NA	NA
Propyl acetate		200 ppm	1,700 ppm	0.18 ppm	Irritated eyes & nose, narcosis	10.07
Propyl alcohol (skin)		200 ppm	800 ppm	5.3 ppm	Drowsiness, headache, nausea stomach pain, drowsiness	10.22
Propylene dichloride		75 ppm	400 ppm	0.50 ppm	Eye irritation, drowsiness, lightheadedness	10.87
Propylene glycol dinitrate (skin)		0.05 ppm	NE	0.24 ppm	Disrupted vision, headache, loss of balance	NA
Propylene glycol monomethyl ether		100 ppm	NE	NA	Eye, nose & throat irritation, tears anesthesia	NA
Propylene imine (skin)		2 ppm	100 ppm	NA	Eye, skin burns, cancer	9.00
Propylene oxide		20 ppm	400 ppm	45 ppm	Irritated eyes, throat & lungs mucous membrane blisters	9.81
Propyl nitrate		25 ppm	500 ppm	NA	Cyanosis, short breath, weakness, headache, very low blood pressure	11.07

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Pyrethrum		5 mg/m³	5,000 mg/m³	NA	Sneezing, asthma, itching, runny nose, cancer	NA
Pyridine		5 ppm	1,000 ppm	0.66 ppm	Headache dizziness, nausea, frequent urination, nervousness	9.27
Quinone		400 µg/m³	100 mg/m³	0.5 ppm	Eye irritation, conjunctivitis corneal ulcers	9.68
^{226}Radium		0.3 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
^{222}Radon						
- with daughters		30 pCi/l	NE	NA	Carcinogen - no warning property	10.7
- without daughters		4,000 pCi/l				
- Radon daughters		0.33 WL				
Resorcinol		10 ppm	NE	40 ppm	Disturbed vision, bronchitis	NA
Rhodium						
(insoluble)		10 µg/m³	100 mg/m³	Dust	Eye irritation, nerve damage	Dust
(soluble)		1 µg/m³	2 mg/m³	Dust	Eye irritation, nerve damage	Dust
Ronnel		10 mg/m³	300 mg/m³	NA	Tears, small pupils, increased sensitivity to noise, salivation	NA
Rosin core solder pyrolysis products		100 µg/m³	NE	NA	Eye, nose & throat irritation, bronchitis	NA
Rotenone		5 mg/m³	2,500 mg/m³	222 mg/m³	Numb mucous membranes, nausea, stomach pain, incoordination	NA
^{106}Ruthenium		40 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
Selenium compounds		200 µg/m³	1 mg/m³	Dust	Headache, chill, fever, garlic breath, disturbed vision	Dust
Selenium hexafluoride		0.05 ppm	2 ppm	NA	Lung irritation, pulmonary edema	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Silica						
(amorphous)		6 mg/m³	3,000 mg/m³	Dust	"Dusty lung", spitting	Dust
(crystalline)		50 µg/m³	25 mg/m³	Dust	Coughing, wheezing, short breath	Dust
Silicon dust		5 mg/m³	NE	Dust	"Dusty lung", Pulmonary fibrosis	Dust
Silicon carbide		5 mg/m³	NE	Dust	"Dusty lung", spitting, coughing	Dust
Silicon tetra-hydride		5 ppm	NE	NA	Blood damage, brown urine, stuffy nose	9.3
Silver dust (metal & soluble)		100 µg/m³ 10 µg/m³	10 mg/m³	Dust	Blue-gray eyes & skin, gastrointestinal irritation	Dust
Soapstone		3 mg/m³	3,000 mg/m³	Dust	Cough, short breath, cyanosis	Dust
Sodium azide (skin)		C-290 µg/m³	NE	NA	Eye irritation, bronchitis, headache, very low blood pressure	11.7
Sodium bisulfite		5 mg/m³	NE	Dust	Eye, nose & throat irritation	Dust
Sodium fluoroacetate (skin)		50 µg/m³	2.5 mg/m³	NA	Hallucinations, face & muscle twitches, numbness	NA
Sodium hydroxide		C-2 mg/m³	10 mg/m³	no odor	Irritated nose, burns eyes & skin pneumonia	9.0
Sodium metabisulfite		5 mg/m³	NE	NA	Eye, nose & throat irritation	NA
Starch (dust)		5 mg/m³	NE	Dust	"Dusty lung", spitting, coughing	Dust
Stearates (dust)		10 mg/m³	NE	Dust	"Dusty lung", spitting, coughing	Dust
Stibine		0.1 ppm	5 ppm	NA	Headache, weakness, nausea, stomach pain, lumbar pain	9.58
Stoddard solvent		100 ppm	20,000 mg/m³	NA	Irritated eyes, nose, throat, dizziness, defatting of skin	<10.4

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
^{90}Strontium		2 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
Strontium chromate		0.5 µg/m³	NE	Dust	Carcinogen - no warning property	Dust
Strychnine		0.15 mg/m³	3 mg/m³	no odor	Stiff neck & face muscles, restlessness, apprehension	NA
Styrene (skin)		50 ppm	700 ppm	0.15 ppm	Irritated eyes & nose, drowsiness, weakness, unsteady gait	8.47
Subtilisins (enzymes)		0.06 µg/m³	NE	NA	Short breath, wheezing, "asthma"	NA
Sucrose dust		5 mg/m³	NE	Dust	None known	Dust
Sulfometuron methyl		5 mg/m³	>100 mg/m³	Dust	Cancer	Dust
Sulfur dioxide		2 ppm	100 ppm	3 ppm	Eye, nose & throat irritation, choking, coughing	12.34
Sulfur hexafluoride		1,000 ppm	NE	NA	"Essentially nontoxic"	15.3
Sulfur chloride		C-1 ppm	5 ppm	9 ppm	Tears, cough, pulmonary edema, skin & eye burns	9.4
Sulfur pentafluoride		C-0.01 ppm	1 ppm	NA	Difficult breath, pulmonary edema	NA
Sulfur tetrafluoride		C-0.1 ppm	NE	NA	Difficult breath, pulmonary edema	NA
Sulfuryl fluoride		5 ppm	200 ppm	NA	Conjunctivitis, runny nose, pharyngitis, numbness	13.0
Sulfuric acid		1 mg/m³	15 mg/m³	>1 mg/m³	Irritated nose & throat, pulmonary edema, conjunctivitis	Mist
Sulprofos		1 mg/m³	NE	NA	Excitement, salivation, small pupils	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
2,4,5-T		10 mg/m³	250 mg/m³	Dust	Incoordination, skin irritation, rash	Dust
Talc (non-asbestos)		2 mg/m³	1,000 mg/m³	Dust	"Dusty lung", spitting, coughing Potential for asbestos content?	Dust
Tantalum		5 mg/m³	2,500 mg/m³	NA	Lung irritation	NA
TEDP (Sulfotep) (skin)		200 µg/m³	10 mg/m³	NA	Tears, cyanosis, nausea local sweating, runny nose	NA
Tellurium		100 µg/m³	25 mg/m³	Dust	Garlic odor on breath, sweating, metal taste, dry mouth, nausea	Dust
Tellurium hexafluoride		0.02 ppm	1 ppm	NA	Headache, dyspnea, garlic odor on breath	NA
Temephos dust		5 mg/m³	NE	Dust	None known	Dust
TEPP (skin)		47 µg/m³	5 mg/m³	NA	Eye pain, tears, chest, nausea runny nose, diarrhea	NA
Terphenyls (skin)		C-0.5 ppm	500 mg/m³	<1 ppm	Irritated eyes, sore throat, headache	8.01
Tetrabromo ethane		1 ppm	8 ppm	NA	Irritated eyes, nose, severe headache, stomach pain	NE
Tetrachloro-difluoroethane		500 ppm	2,000 ppm	NA	Irritated skin, conjunctivitis, pulmonary edema	11.3
1,1,2,2-Tetra-chloroethane (skin)		1 ppm	150 ppm	7.3 ppm	Nausea, stomach pain, finger tremors	11.1
Tetrachloro-ethylene		25 ppm	150 ppm	47 ppm	Irritated eyes, nose, throat, flushed face & neck, dizziness	9.32
Tetrachloro-naphthalene (skin)		2 mg/m³	≤20 mg/m³	NA	Acne, headache, fatigue, vertigo	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Tetraethyl lead (skin)		75 µg/m³	40 mg/m³	NA	Fatigue, anxiety, tremors, nausea, convulsions	11.1
Tetrahydrofuran		200 ppm	2,000 ppm	31 ppm	Nausea, dizziness, headache	9.45
Tetramethyl lead (skin)		75 µg/m³	40 mg/m³	NA	Restless, anxious, nausea, mania	8.50
Tetramethyl succinonitrile (skin)		0.5 ppm	5 ppm	NA	Headache, nausea, convulsions	NA
Tetranitromethane		0.005 ppm	4 ppm	0.4 ppm	Irritated eyes, dizziness, headache, cyanosis, chest pain	NA
Tetrasodium pyro-phosphate		5 mg/m³	NE	NA	Eye, nose & throat irritation	NA
Tetryl (skin)		1.5 mg/m³	750 mg/m³	NA	Sensitive skin, itching, headache	NA
Thallium (skin)		100 µg/m³	15 mg/m³	NA	Nausea, diarrhea, stomach pain	NA
Thiobis(t-butyl) cresol		5 mg/m³	NE	NA	Gastroenteritis, lung damage	NA
Thioglycolic acid (skin)		1 ppm	NE	NA	Weakness, difficult breath, convulsions	NA
Thionyl chloride		C-1 ppm	NE	NA	Eye, nose, skin & throat irritation	NA
Thiram		1 mg/m³	100 mg/m³	NA	Nose & throat irritation, (with alcohol) flushing, vomiting	NA
^{230}Thorium		0.003 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
Thoron (^{220}Rn)						
- without progeny		7,000 pCi/l	NE	NA	Carcinogen - no warning property	NA
- with progeny		9 pCi/l	NE	NA	Carcinogen - no warning property	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Tin						
- inorganic		2 mg/m³	100 mg/m³	NA	Irritated eyes & skin, headache	NA
- organic (skin)		100 µg/m³	25 mg/m³	NA	mental disturbance, sore throat	NA
Titanium dioxide		10 mg/m³	5,000 mg/m³	Dust	"Dusty lung", spitting, coughing	Dust
Tolidine (skin)		20 µg/m³	NE	NE	Carcinogen - no warning property	NE
Toluene (skin)		50 ppm	500 ppm	1.7 ppm	Fatigue, confusion, euphoria, dizziness, headache, tears	8.82
Toluene-2,4-diisocyanate (TDI)		0.005 ppm	2.5 ppm	2.14 ppm	Irritated nose, throat, choking, pulmonary edema, asthma	NA
Toluidine (skin)		2 ppm	50 ppm	20 ppm	Headache, cyanosis, dizziness, drowsiness, burning eyes	7.44
Tributyl phosphate		0.2 ppm	30 ppm	NA	Respiratory irritation, headache, nausea	NA
Trichloroacetic acid		1 ppm	NE	NA	Burns to the skin or eye	NA
Trichlorobenzene		C-5 ppm	NE	NA	Nose & eye irritation	NA
1,1,1-Trichloroethane		350 ppm	700 ppm	400 ppm	Headache, CNS depression, loss of balance, eye irritation	11.0
1,1,2-Trichloroethane (skin)		10 ppm	100 ppm	NA	Irritated nose, central nervous system depression	11.0
Trichloroethylene		50 ppm	1,000 ppm	82 ppm	Vertigo, visual disturbance, headache, drowsiness	9.45
Trichlorofluoromethane		C-1,000 ppm	2,000 ppm	no odor	Incoordination, cardiac arrhythmia tremors	11.8
Trichloronaphthalene (skin)		5 mg/m³	≤20 mg/m³	NA	"Acne", nausea, lost appetite, vertigo	NA

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
1,2,3-Trichloro-propane (skin)		10 ppm	100 ppm	100 ppm	Irritated eyes, throat, central nervous system depression	NA
Trichloro-trifluoroethane		1,000 ppm	2,000 ppm	45 ppm	Irritated throat, drowsiness	11.99
Triethylamine		1 ppm	200 ppm	0.28 ppm	Irritated eyes, lungs & skin excitement, salivation, tremors	7.5
Trifluoro-bromomethane		1,000 ppm	40,000 ppm	NA	Lightheadedness, cardiac arrhythmias	11.4
Trimellitic anhydride		0.005 ppm	NE	NA	Runny nose, wheezing, "asthma" Eye, nose & throat irritation	NA
Trimethylamine		5 ppm	NE	0.002 ppm	Eye, nose & throat irritation, pneumonia	7.82
Trimethyl benzene		25 ppm	NE	2.4 ppm	Eye, nose & throat irritation, pneumonia	NA
Trimethyl phosphite		2 ppm	NE	0.1 ppb	Corneal ulcers	NA
2,4,6-Trinitro-toluene (TNT) (skin)		500 µg/m³	500 mg/m³	Solid	Throat irritation, coughing headache, sneezing, foot drop	10.59
Triorthocresyl phosphate (skin)		100 µg/m³	40 mg/m³	NA	Gastrointestinal pain, cramps in calves, foot or wrist drop	NA
Triphenyl amine		5 mg/m³	NE	NA	None known	6.86
Triphenyl phosphate		3 mg/m³	1,000 mg/m³	NA	Muscle weakness, paralysis	NA
Tritium (^{3}H)		20,000 pCi/l	NE	None	Carcinogen. No warning property.	>13
Tungsten compounds (soluble)		5 mg/m³ 1 mg/m³	NE NE	Dust Dust	Lost appetite, incoordination, tremors, difficult breathing	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
Turpentine		100 ppm	800 ppm	200 ppm	Irritated eyes, nose, throat, headache, blood in urine	NA
Uranium & compounds						
- insoluble		200 µg/m³	10 mg/m³	Dust	Dermatitis, lung damage, cancer	Dust
- soluble		50 µg/m³	10 mg/m³	Dust	tears, cough, nausea, short breath	Dust
Valeraldehyde		50 ppm	NE	12 ppm	Eye, nose & throat irritation	NA
Vanadium (dust)		50 µg/m³	35 mg/m³	Dust	Green tongue, metal taste, coughing, throat irritation	Dust
Vegetable oil mist		5 mg/m³	NE	Mist	None known	Mist
Vinyl acetate		10 ppm	NE	0.12 ppm	Eye, nose & throat irritation	9.19
Vinyl bromide		5 ppm	Carc.	NA	Eye irritation, cancer	9.80
Vinyl chloride		1 ppm	Carc.	NA	Weakness, stomach pain, cancer	10.0
Vinyl cyclohexene		0.1 ppm	Carc.	NA	Skin, eye, nose & throat irritation,	<10.0
Vinyl cyclohexene dioxide (skin)		10 ppm	Carc.	NA	Skin, eye, nose & throat irritation, cancer	8.93
Vinyl toluene		50 ppm	400 ppm	50 ppm	Irritated eyes, upper respiratory difficulties, drowsiness	8.20
V M & P Naphtha		300 ppm	NE	NA	Eye irritation, bronchitis	NA
Warfarin		100 µg/m³	100 mg/m³	no odor	Back pain, bloody nose & lips membrane hemorrhaging, vomiting, bruises	NA
Welding fumes		5 mg/m³	NE	Dust	"Dusty lung", spitting, coughing	Dust
Wood dust (NOS)		5 mg/m³	NE	Dust	"Dusty lung", spitting, coughing	Dust
(red cedar)		2.5 mg/m³	NE	Dust	Dermatitis, "asthma", wheezing	Dust
(beech & oak)		1 mg/m³	NE	Dust	"Dusty lung", spitting, coughing, nasal cancer	Dust

Material	Concentration	PEL/TLV	IDLH	Warning	Signs & Symptoms	IP (eV)
X-Rays and Gamma Radiation		2,000 µR/hr (Company-internal)	100 R/hr	NA	carcinogen - no warning property	NA
Xylene		100 ppm	900 ppm	5 ppm	Eye, nose & throat irritation, drowsiness, nausea, incoordination	8.44
Xylene diamine (skin)		C-100 µg/m³	NE	100 ppm	Skin, eye, nose & throat irritation, difficult breathing, tears	NA
Xylidine (skin)		0.5 ppm	150 ppm	0.40 ppm	Headache, weakness, cyanosis	7.65
Yttrium		1 mg/m³	500 mg/m³	Dust	Irritated eyes & lungs, liver damage	Dust
^{90}Yttrium		300 pCi/l	NE	Dust	Carcinogen - no warning property	Dust
Zinc chloride fume		1 mg/m³	50 mg/m³	Dust	Irritated nose, throat, cough, short breath, spitting	12.9
Zinc chromate		10 µg/m³	15 mg/m³	Dust	Cancer upon chronic exposure	Dust
Zinc (dusts) (fumes)		10 mg/m³ 5 µg/m³	NE NE	Dust Dust	Sweet metal taste, dry throat, cough, tight chest, chills	Dust
Zirconium dusts		5 mg/m³	50 mg/m³	Dust	Skin, nose, & throat irritation	Dust
^{95}Zirconium		50 pCi/l	NE	Dust	Carcinogen - no warning property	Dust

Exhibit B **Occupational and Ambient Level Limits**

TABLE 1
VOLATILE ORGANIC CHEMICAL ANALYTES

Chemical Name	Occupational Exposure Limit	Ambient Air Guideline
Chloromethane	50 ppm	2,500 $\mu g/m^3$
Bromomethane	5 ppm	
Vinyl chloride	1 ppm	0.4 $\mu g/m^3$
Chloroethane	1000 ppm	52,000 $\mu g/m^3$
Methylene chloride	50 ppm	1.167 $\mu g/m^3$
Acetone	750 ppm	35,600 $\mu g/m^3$
Carbon Disulfide	4 ppm	100 $\mu g/m^3$
1,1 Dichloroethane	100 ppm	
1,1 Dichloroethene	5 ppm	67 $\mu g/m^3$
1,2 Dichloroethene	200 ppm	1,880 $\mu g/m^3$
Chloroform	2 ppm	167 $\mu g/m^3$
2 - Butanone	200 ppm	1,967 $\mu g/m^3$
1,1,1 Trichloroethane	350 ppm	38,000 $\mu g/m^3$
Carbon tetrachloride	2 ppm	100 $\mu g/m^3$
Vinyl Acetate	10 ppm	
Bromo Dichloromethane		0.03 $\mu g/m^3$
Tetrachloroethane	1 ppm	23 $\mu g/m^3$
1,2 dichloropropane	75 ppm	833 $\mu g/m^3$
Trichloroethene	50 ppm	900 $\mu g/m^3$
Dibromochloromethane		
1,1,2 Trichloroethane	10 ppm	150 $\mu g/m^3$
Benzene	1 ppm	100 $\mu g/m^3$
1,3 Dichloropropene	1 ppm	
Bromoform	0.5 ppm	11.9 $\mu g/m^3$
2 Hexanone	5 ppm	
4 Methyl 2 pentanone	50 ppm	683 $\mu g/m^3$
Tetrachloroethene	25 ppm	23 $\mu g/m^3$
Toluene	50 ppm	7,500 $\mu g/m^3$
Chlorobenzene	10 ppm	1,167 $\mu g/m^3$
Ethylbenzene	100 ppm	1,450 $\mu g/m^3$
Styrene	50 ppm	716 $\mu g/m^3$
Xylene	100 ppm	1,450 $\mu g/m^3$
Trichlorotrifluoroethane	1,000 ppm	90,476 $\mu g/m^3$

Exhibit B **Occupational and Ambient Level Limits**

TABLE 2

NON-VOLATILE ORGANIC ANALYTES

Chemical Name	Occupational Exposure Limit	Ambient Air Guideline
Aldehydes (formaldehyde)	0.37 mg/m³	
Hydrogen Cyanide	5 mg/m³	33 μg/m³
Hydrogen Sulfide	14 mg/m³	10 μg/m³
Isophorone	4 ppm	83 μg/m³
Dinitrotoluene	0.15 mg/m³	
Mineral Acids		
Hydrochloric Acid (ceiling)	7 mg/m³	140 μg/m³
Nitric acid	5 mg/m³	100 μg/m³
Sulfuric acid	1 mg/m³	1,000 μg/m³
Polycyclic Aromatics	0.2 mg/m³	carc
Naphthalene	10 ppm	167 μg/m³
Phenols		
2-Chlorophenol		
Cresols (methyl phenols)	22 mg/m³	73 μg/m³
o-Isobutylphenol	305 mg/m³	
4-Methoxyphenol	5 mg/m³	
Pentachlorophenol	0.5 mg/m³	1.67 μg/m³
Phenol	19 mg/m³	10 μg/m³

THE CHEMICAL PROCESS INDUSTRIES

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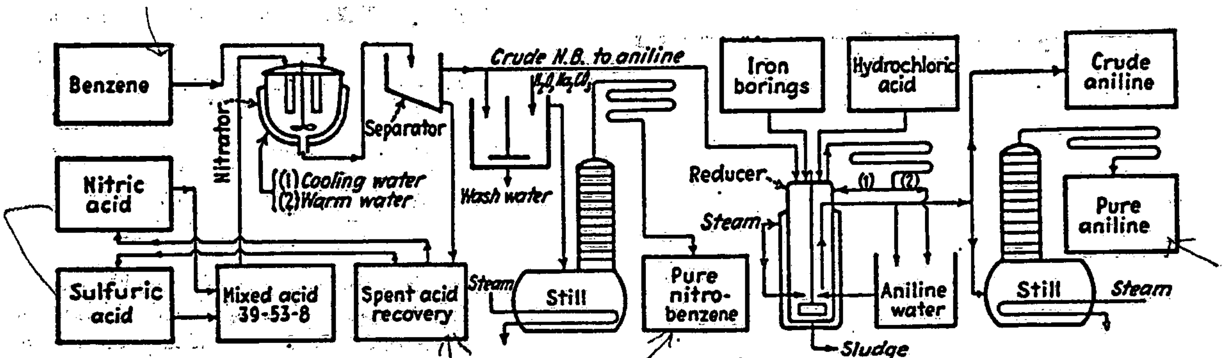


Nitrobenzene

Benzene		1,310 lb.	Per ton Nitrobenzene
Mixed acid	HNO_3	1,060 lb.	
	H_2SO_4	1,442 lb.	
	H_2O	218 lb.	
Sodium carbonate		20 lb.	
Power (% total cost)		32	
Labor (% total cost)		24	
Overhead (% total cost)		83	

Aniline

Nitrobenzene	2,780 lb.	Per ton Aniline
Iron borings	3,200 lb.	
HCl (30%)*	250 lb	
Power (% total cost)	6.4	
Labor (% total cost)	8.0	
Overhead (% total cost)	4.0	

*or an equivalent amount of aniline salt mother liquor

FIG. 1. Flow sheet for nitro-benzene and aniline.

Riegel's

Handbook of Industrial Chemistry

NINTH EDITION

Edited by

James A. Kent, Ph.D.

VNR VAN NOSTRAND REINHOLD
New York

TABLE 28.22 Physical Properties of Aniline

Property	*Value*
Boiling point, °C	
101.3 kPa (760 mm Hg)	184.4
4.4 kPa (33 mm Hg)	92
1.2 kPa (9 mm Hg)	71
Melting point, °C	−6.15
Density, *d*	
at 20/4°C	1.02173
at 20/20°C	1.022
Viscosity at 20°C, mPa·s (=cP)	4.423–4.435
Dissociation constant, *pK*	
at 20°C	4.60
at 60°C	8.88
Enthalpy of dissociation, kJ/mol (kcal/mol)	21.7 (5.19)
Heat of combustion, kJ/mol (kcal/mol)	3389.72 (810.55)
Specific heat, 20–25°C	0.518
Latent heat of vaporization, J/g (cal/g)	476.3 (113.9)
Flash point (closed-cup), °C	76

TABLE 28.23 Vapor Pressure of Aniline

Temperature °C	*Vapor Pressure kPa*	*Temperature °C*	*Vapor Pressure kPa*
175	79.99	139	27.67
162	53.33	119	13.33
151	39.99	102	6.67

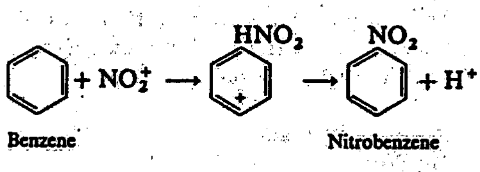
ANILINE

Aniline or aminobenzene (benzamine) was produced first in 1826 by Unverdorben, by the dry distillation of indigo, the oldest known vat dye. Fritsche also obtained this material from indigo by heating it with potash, and he named it aniline. Hofmann obtained it by reduction of nitrobenzene in 1843, proving the structure. Aniline is a colorless, oily, flammable liquid, which is slightly soluble in cold water and infinitely soluble in alcohol and ether. It is highly toxic with a threshold limit value of 5 ppm by volume. Its physical properties are summarized in Table 28.22, and its vapor pressure characteristics in Table 28.23.

Aniline is produced from nitrobenzene, which, in turn, is produced by reacting nitric acid with benzene at 50°C in the presence of sulfuric acid. The reaction is postulated to proceed as follows:

$$HONO_2 + H^+ \rightarrow H_2ONO_2^+$$

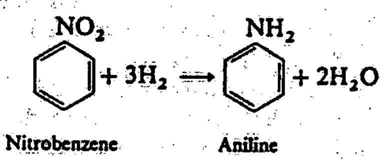
$$H_2ONO_2^+ \rightleftharpoons H_2O + NO_2^+ \text{ (nitronium ion)}$$



In concentrated sulfuric acid, HNO_3 is completely converted to NO_2^+, thus favoring the nitration reaction.

Impurities in the nitrobenzene result from impurities in the benzene such as nitrocresols, and other nitration products such as nitrous acid, nitrogen oxides, dinitrobenzene, nitrotoluene, carbolic acid, and nitrophenols. More details on the production of nitrobenzene are reviewed in Chapter 23.

Aniline is produced by hydrogenation of the nitrobenzene amine group to an amino group. A catalyst is used such as copper/silica, nickel, or platinum/palladium. The reaction can be carried out in either the vapor or the liquid phase at 250 to 300°C and 10 to 25 atmospheres.



Yields from nitrobenzene are reported to be greater than 99 percent of theoretical.

Some aniline still is produced by reducing nitrobenzene with iron in the presence of ferrous chloride and/or hydrochloric acid.

The Scientific Design, Inc. process for aminolysis of phenol is shown in Fig. 28.31.[122] In this process, a mixed-vapor feed of phenol and ammonia is preheated and passed over a fixed catalyst bed. A unique SD-developed catalyst is used. The reactor effluent is partially condensed and then sent to an ammonia recovery still. The recovered ammonia is recycled, and the ammonia recovery still bottoms are stripped of ammonia, dried, and distilled. Nearly stoichiometric yields are said to be obtained, and the aniline is of high purity. An azeotrope of aniline and phenol from the purification still is recycled to the reactor, and a long catalyst life is claimed. A 30,000 metric ton/year plant has been operated by Mitsui Petrochemical Industries, Ltd. since 1970. In 1882, U.S. Steel put a 90,000 metric ton/year plant onstream. This process is favorable where low cost phenol is available, and when high purity aniline is desired. Capital costs are low because the nitration of benzene is avoided. Waste disposal problems are minimal.

Reduction of nitrobenzene also can be carried out in the liquid phase with H_2S, but this is not a commercial process at present.

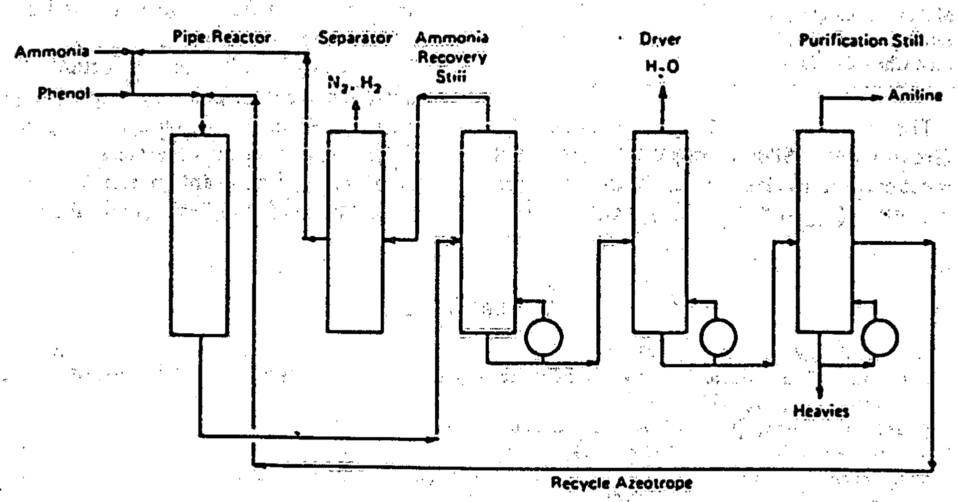


Fig. 28.31. Aniline by aminolysis of phenol. ("*Aniline,*" Hydrocarbon Processing, Petrochemical Handbook *issue, p. 124, Nov. 1985. Copyright by Gulf Publishing Company. By permission.*)

A fixed bed of catalyst is used in the Lonaz process, which has been installed at the First Chemical Corp. plant in Pascagoula, Mississippi.[123] The plant design rate is 250,000 lb/year. Yield is about 85 percent, or 1.35 lb of nitrobenzene/lb of aniline.

Aminolysis of chlorobenzene also will produce aniline although it probably is not used commercially.

$$\underset{\text{Chlorobenzene}}{C_6H_5Cl} + 2NH_3 \rightarrow \underset{\text{Aniline}}{C_6H_5NH_2} + NH_4Cl$$

For the aminolysis of chlorobenzene, 3 moles of ammonia usually are used at an operating temperature of 180 to 200°C and a pressure greater than the vapor pressure of the reactants. This reaction is carried out in the liquid phase with copper compounds as catalysts.

Aniline is used primarily for the production of 4,4'-methylenebis(phenylisocyanate) which consumes about 75 percent of the aniline produced. Other products include rubber chemicals (13%), dyestuffs (3%), synthetic fibers (2%), pharmaceuticals (1%), and agricultural chemicals (6%). U.S. producers of aniline and their capacities are:

	Million pounds per year
Aristech Chemical Corp.	200
E. I. Du Pont de Nemours and Co.	260
Mobay Chemical Corp.	40
Rubicon Chemicals, Inc.	360
First Chemical Corp.	250

The demand in 1988 was 1 billion lb. Growth in the 1980s averaged 4.2 percent, but most came in the last half of the decade when growth averaged 8.5 percent/year.

The list price for aniline in 1991 was 50 cents/lb in tank cars, f.o.b.[46] Process licensers for aniline in 1990 were:[47]

American Cyanamid
Du Pont
Lonza
Josef Meissner
Mitsui Toatsu
Petroquisa/Pronor
Scientific Design
Sumitomo Chemicals
Tolochimie

OTHER COMPOUNDS

Several other nitrogen compounds are of commercially important, including:

- Hexamethylenediamine (Chapter 21), used primarily in the manufacture of nylon.
- Ethanolamines (Chapter 22), used in the manufacture of detergents and as scrubbing agents for the removal of acidic compounds from gases.
- Acrylonitrile (Chapters 18, 19, 21, and 22), used in the manufacture of acrylic and modacrylic fibers, plastics and resins, and nitrile rubbers or elastomers.
- Dimethylformamide, a versatile solvent for organic and inorganic compounds and an important reaction medium for ionic and nonionic compounds.
- Dimethylacetamide, an important industrial solvent for polyacrylonitrile, vinyl resins, cellulose derivatives, styrene polymers, and linear polyesters.
- Isocyanates, important materials in the production of foams, resins, and rubbers.

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7. U.S. Patent 4,153,673.

Exhibit D

Axonmeter.WQ2 Example

Upgrade Downgrade Information for Volatile Compounds in Air
Name of Site ____________________

CONTAMINANT	Exposure Limit (OSHA) (ppm)	IDLH (ppm)	Upgrade Level (C/B)	Ion Potent (eV)	C?	Response Factor% (PID) @10.2eV	½ EL Readng on PID (ppm)	⅓ IDLH Readng on PID (ppm)	½ IDLH Readng on PID (ppm)
Acetone	750	20000	C	9.69		63	236.3	4200.0	6300.0
Benzene	1	3000	C	9.24		100	0.5	1000.0	1500.0
Bromochloromethane	200	5000	B	10.80		0	0.0	0.0	0.0
Carbon Disulfide	4	500	C	10.08		71	1.4	118.3	177.5
Carbon Tetrachloride	2	300	B	11.47		0	0.0	0.0	0.0
Chlorobenzene	10	2400	C	9.07		100	5.0	800.0	1200.0
Chloroform	2	1000	B	11.42		0	0.0	0.0	0.0
Dibromochloromethane	1		B	9.07	*	0	0.0	0.0	0.0
Dichlorobenzenes	75	1000	C	8.98		130	48.8	433.3	650.0
1,1-Dichloroethane	100	4000	C	11.06		0	0.0	0.0	0.0
1,1-Dichloroethene	1	500	B	10.00	*	70	0.4	116.7	175.0
1,2-Dichloroethene	200	4000	C	9.65	*	70	70.0	933.3	1400.0
1,4-Dioxane	25	2000	B	9.13	*	100	12.5	666.7	1000.0
Ethylbenzene	100	2000	C	8.76		116	58.0	773.3	1160.0
Ethyl Chloride	1000	20000	B	10.97		0	0.0	0.0	0.0
Methyl Butyl Ketone	5	5000	B	9.34		52	1.3	866.7	1300.0
Methyl Chloride	50	10000	B	11.28		0	0.0	0.0	0.0
Methyl Ethyl Ketone	200	3000	C	9.54		57	57.0	570.0	855.0
Methylene Chloride	50	5000	B	11.32		0	0.0	0.0	0.0
Naphthalene	10	500	C	8.12		197	9.9	328.3	492.5
Propylene Dichloride	75	2000	C	10.87		0	0.0	0.0	0.0
Styrene	50	5000	C	8.40		97	24.3	1616.7	2425.0
Tetrachloroethane	1	150	B	11.10		0	0.0	0.0	0.0
Tetrachloroethylene	25	500	C	9.32	*	75	9.4	125.0	187.5
Toluene	50	2000	C	8.82		100	25.0	666.7	1000.0
1,1,1-Trichloroethan	350	1000	C	11.00		0	0.0	0.0	0.0
Trichloroethylene	50	1000	C	9.45		89	22.3	296.7	445.0
Vinyl Chloride	1	CARC.	B	9.99		50	0.3	0.0	0.0
Xylene	100	1000	C	8.44		112	56.0	373.3	560.0

Exhibit E **DustLevl.WQ2 Example**

Name of Site Safety factor for this site = 2

Chemical	Exposure Limit (mg/m³)	Maximum Soil Level in (mg/kg)	Dust Limit Based on This Compound (mg/m3)	"Quotient" for This Compound (level/limit)
Aluminum	5	1E-09	2.5E+15	2.00E-10
Antimony	0.5	1E-09	2.5E+14	2.00E-09
Arsenic	0.01	255	2.0E+01	2.55E+04
Barium	0.5	1E-09	2.5E+14	2.00E-09
Beryllium	0.002	255	3.9E+00	1.28E+05
Cadmium	0.005	255	9.8E+00	5.10E+04
Cs-137(pCi/l)	60	1E-09	3.0E+16	1.67E-11
Chlordane	1	1E-09	5.0E+14	1.00E-09
Chromium	0.5	1E-09	2.5E+14	2.00E-09
Chrome (hex)	0.01	1E-09	5.0E+12	1.00E-07
Cobalt	0.02	1E-09	1.0E+13	5.00E-08
Copper	1	255	2.0E+03	2.55E+02
Cyanides	5	255	9.8E+03	5.10E+01
Endosulfan	0.1	1E-09	5.0E+13	1.00E-08
Fluorides	2.5	1E-09	1.3E+15	4.00E-10
Lead	0.05	255	9.8E+01	5.10E+03
Manganese	1	1E-09	5.0E+14	1.00E-09
Mercury	0.05	255	9.8E+01	5.10E+03
Nickel	1	1E-09	5.0E+14	1.00E-09
Oil Mist	5	1E-09	2.5E+15	2.00E-10
PCBs	0.5	46	5.4E+03	9.20E+01
PNAs	0.2	255	3.9E+02	1.28E+03
Phthalates	5	1E-09	2.5E+15	2.00E-10
Pu-239(pCi/l)	0.003	1E-09	1.5E+12	3.33E-07
Ra-226(pCi/l)	0.3	1E-09	1.5E+14	3.33E-09
RDX	1.5	1E-09	7.5E+14	6.67E-10
Selenium	0.2	255	3.9E+02	1.28E+03
Silica	0.05	1E-09	2.5E+13	2.00E-08
Silver	0.01	1E-09	5.0E+12	1.00E-07
Sr-90(pCi/l)	8	1E-09	4.0E+15	1.25E-10
Thallium	0.1	1E-09	5.0E+13	1.00E-08
Th-230(pCi/l)	0.003	1E-09	1.5E+12	3.33E-07
Tin	2	1E-09	1.0E+15	5.00E-10
Titanium	10	1E-09	5.0E+15	1.00E-10
Trinitrobenze	0.07	1E-09	3.5E+13	1.43E-08
Trinitrotolue	0.5	1E-09	2.5E+14	2.00E-09
Vanadium	0.05	25	1.0E+03	5.00E+02
Zinc	5	3400	7.4E+02	6.80E+02
			Sum =	2.18E+05

Dust Exposure Level @ PEL for Mixture = 2.29

Exhibit F **Vapor.WQ2 Example**

"WORST CASE" VAPOR EXPOSURE CALCULATION for volatile compounds in water

PARAMETER: CONTAMINANT	MAXIMUM CONCENTR'N (site water) (µg/l)	Water Solubility (pure) mg/l	Vapor Pressure When Pure (torr)	Exposure Limit (OSHA) (ppm)	Saturat'n Concentr'n in Air (ppm)	Fraction of Total vapor in Air (% by ppm)	Saturat'n Concentr'n in Air % of PEL
Acetone	4100	3000000	180	750	0.324	0.03%	0.04%
Benzene	25	600	75	1	4.111	0.43%	411.09%
Bromochloromethane	1E-09	10000	300	200	0.000	0.00%	0.00%
Carbon Disulfide	1E-09	2000	300	4	0.000	0.00%	0.00%
Carbon Tetrachlorid	1E-09	800	91	2	0.000	0.00%	0.00%
Chlorobenzene	1E-09	500	11.8	10	0.000	0.00%	0.00%
Chloroform	1E-09	7950	246	2	0.000	0.00%	0.00%
Dibromochloromethan	1E-09	4700	50	1	0.000	0.00%	0.00%
Dichlorobenzenes	1E-09	156	1.47	75	0.000	0.00%	0.00%
1,1-Dichloroethane	1E-09	5060	227	100	0.000	0.00%	0.00%
1,1-Dichloroethene	1E-09	2500	591	1	0.000	0.00%	0.00%
1,2-Dichloroethene	1E-09	800	200	200	0.000	0.00%	0.00%
1,4-Dioxane	1E-09	2000000	30	25	0.000	0.00%	0.00%
Ethylbenzene	1E-09	150	7.1	100	0.000	0.00%	0.00%
Ethyl Chloride	1E-09	5740	900	1000	0.000	0.00%	0.00%
Methyl Butyl Ketone	3500	5000000	3.8	5	0.003	0.00%	0.07%
Methyl Chloride	1E-09	4800	3756	50	0.000	0.00%	0.00%
Methyl Ethyl Ketone	1000	3560000	100	200	0.037	0.00%	0.02%
Methylene Chloride	8600	13000	435	50	378.560	39.59%	757.12%
Naphthalene	1E-09	31.7	0.082	10	0.000	0.00%	0.00%
Propylene Dichlorid	1E-09	2600	40	75	0.000	0.00%	0.00%
Styrene	1E-09	300	7	50	0.000	0.00%	0.00%
Tetrachloroethane	1E-09	2900	7	1	0.000	0.00%	0.00%
Tetrachloroethylene	1E-09	150.3	18.49	25	0.000	0.00%	0.00%
Toluene	1300	500	25	50	85.508	8.94%	171.02%
1,1,1-Trichloroetha	1E-09	4400	124	350	0.000	0.00%	0.00%
Trichloroethylene	1E-09	1100	75	50	0.000	0.00%	0.00%
Vinyl Chloride	1E-09	1100	760	1	0.000	0.00%	0.00%
Xylene	7300	130	6.6	100	487.545	50.99%	487.54%
		Combined Volatiles Level (ppm)			956.090	100.00%	
				Fraction Combined Exposure Limit			18.269

Exhibit G **SoilVapr.WQ2 Example**

Name of Site and Area

"WORST CASE" VAPOR EXPOSURE CALCULATION
for volatile compounds in soil Carbon in Soil (frxn) 0.02

PARAMETER: CONTAMINANT	MAXIMUM CONCENTR'N (site soil) (mg/Kg)	Water Solubility (pure) mg/l	Vapor Pressure (pure) (torr)	Partition Cofishent Koc (fraxion)	Exposure Limit (OSHA) (ppm)	Saturation Concentr'n over soil (ppm)	Fraction of Total vapor in Air (percent)	Saturation Concentr'n in Air % of PEL
Acetone	255	3000000	180	0.23	750	4375.467	38.07%	583.40%
Acrylonitrile	1E-09	79000	100	0.85	2	0.000	0.00%	0.00%
Benzene	0.32	600	95	83	1	40.152	0.35%	4015.18%
Bromochloromethane	1E-09	10000	300	13	200	0.000	0.00%	0.00%
Carbon Disulfide	1E-09	2000	300	54	4	0.000	0.00%	0.00%
Carbon tetrachloride	1E-09	800	91	110	2	0.000	0.00%	0.00%
Chlorobenzene	1E-09	500	11.8	330	10	0.000	0.00%	0.00%
Chloroform	1E-09	7950	246	31	2	0.000	0.00%	0.00%
Dichlorobenzenes	1E-09	156	1.47	1700	75	0.000	0.00%	0.00%
1,1-Dichloroethane	0.009	5060	227	30	100	0.885	0.01%	0.89%
1,1-Dichloroethene	1E-09	2500	591	65	1	0.000	0.00%	0.00%
1,2-Dichloroethene	25	800	200	59	200	6967.691	60.62%	3483.85%
1,4-Dioxane	1E-09	2000000	30	3.5	25	0.000	0.00%	0.00%
Ethyl Benzene	1E-09	150	7.1	1100	100	0.000	0.00%	0.00%
Ethyl Chloride	1E-09	5740	900	11	1000	0.000	0.00%	0.00%
Formaldehyde	1E-09	400000	10	3.6	0.3	0.000	0.00%	0.00%
Methyl Butyl Ketone	1E-09	5000000	3.8	9.8	5	0.000	0.00%	0.00%
Methyl Chloride	1E-09	4800	3756	35	50	0.000	0.00%	0.00%
Methyl Ethyl Ketone	1E-09	3560000	100	4.5	200	0.000	0.00%	0.00%
Methylene Chloride	1E-09	13000	435	8.8	50	0.000	0.00%	0.00%
Naphthalene	31000	31.7	0.082	400	10	107.871	0.94%	1078.71%
Styrene	1E-09	300	7	365	50	0.000	0.00%	0.00%
Tetrachloroethane	1E-09	2900	7	118	1	0.000	0.00%	0.00%
Tetrachloroethylene	1E-09	150.3	18.49	364	25	0.000	0.00%	0.00%
Toluene	1E-09	500	25	300	50	0.000	0.00%	0.00%
Triethylamine	1E-09	15000	54	11.3	1	0.000	0.00%	0.00%
1,1,1-Trichloroethan	0.12	4400	124	152	350	1.463	0.01%	0.42%
Trichloroethylene	1E-09	1100	75	126	50	0.000	0.00%	0.00%
Vinyl Chloride	1E-09	1100	760	57	1	0.000	0.00%	0.00%
Xylene	1E-09	130	6.6	240	100	0.000	0.00%	0.00%